VOLUME 42 DECEMBER, 1952 NUMBER 12

Phytopathology

An International Journal

Official Organ of

THE AMERICAN PHYTOPATHOLOGICAL SOCIETY

JAN 26 1953

SCIENCE LIBRARY

CONTENTS

Pathogenic behavior of certain root-knot nematodes, Meloidogyne spp., on snapdragon, Antirrhinum majus L. — A. C. Tarjan 637

Comparative studies of some root-knot nematodes infecting the common snapdragon, Antirrhinum majus L. — A. C. Tarjan 641

Variation in pathogenicity among isolates of Phytophthora infestans on tomato and potato — Paul E. Waggoner and J. R. Wallin 645

Methods for reducing the spread of the witch's broom disease in alfalfa — J. D. Menzies 649

Paratylenchus hamatus pathogenic to celery — B. F. Lownsbery, E. M. Stoddard and J. W. Lownsbery 651

Purple leafspot of orchard grass — J. M. Graham 653

The vitamin nutrition of Alternaria solani — Ralph W. Lewis 657

The inheritance of resistance to frog-eye leaf spot of soybeans — Kirk Athow and A. H. Probst 660

Studies on the nature of the specific transmission of aster-yellows and corn-stunt viruses — Karl Maramorosch 663

Blight of Amaranthus paniculatus L. caused by Alternaria — N. S. Venkatakrishnaiah 668

A comparative study of two species of Colletotrichum on vetch — Norman L. Horn 670

Observations on crazy top of corn — Arnold J. Ullstrup 675

Observations on the production of mycelial mats of the oak wilt fungus in Pennsylvania — C. L. Morris and C. L. Fergus 681

Leaf fleck, an aphid borne persistent virus disease of maize — Warren N. Stoner 683

Phytopathological Notes:

The formation of rod-shaped particles resembling tobacco mosaic virus by polymerization of a protein from mosaic-diseased tobacco leaves — William N. Takahashi and Mamoru Ishii 690

The formation of perithecia of Chalara quercina in nature in West Virginia — J. M. Staley and R. P. True 691

A new method for application of chloropicrin in warehouse fumigation — Norman D. Dorie, Roy A. Young, J. B. Rogers and J. A. Milbrath 693

Two races of Fusarium oxysporum f. perniciosum causing wilt of Albizzia spp. — E. Richard Toole 694

News

Index to Volume 42

Subscription, $10.00 per year

Office of Publication—Monumental Printing Company, Baltimore, Md.

Entered as second-class matter at the post office at Baltimore, Md.

DuPont Announces MANZATE

TRADE MARK

FUNGICIDE

for TOMATOES and POTATOES

Based on Manganese Ethylene Bisdithiocarbamate

EXPERIMENTAL QUANTITIES NOW AVAILABLE

"Manzate", sixth in a series of dithiocarbamate fungicides offered by Du Pont, has special advantages on tomatoes and potatoes. It has already given a highly satisfactory account of itself in many states this year where it has been evaluated in carefully conducted tests and has also been used by commercial growers in all the principal tomato producing states. This substantiates results previously obtained in several years' tests in 32 states, Hawaii, Canada and Mexico.

FOR TOMATOES—"Manzate" fungicide is a single material effective against all the major fungous diseases of tomatoes. Now a program is offered employing "Manzate" alone to control diseases instead of alternate chemicals in separate sprays. "Manzate" is effective against early and late blight, anthracnose, gray leaf spot (Stemphylium), and Septoria leaf spot.

FOR POTATOES—"Manzate" is particularly effective against both early blight and late blight, especially when both these diseases are severe at the same time.

At present, Du Pont's recommendations for use of "Manzate" apply only to tomatoes and potatoes. As a result of numerous tests conducted during the past season on certain other crops it appears that "Manzate" will have a much wider range of application. Experimental quantities of "Manzate" fungicide are now available for research purposes. "Manzate" will be tested still further on additional crops in 1953. For further information, write Du Pont, Grasselli Chemicals Department, Wilmington, Delaware.

DU PONT

REG. U.S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING

. . . *THROUGH CHEMISTRY*

PATHOGENIC BEHAVIOR OF CERTAIN ROOT-KNOT NEMATODES, MELOIDOGYNE SPP., ON SNAPDRAGON, ANTIRRHINUM MAJUS L.[1]

A. C. Tarjan[2]

For some time the degree of pathogenicity of the root-knot nematode to various crops has been the subject of extensive investigations. Numerous inconsistencies in results have indicated the possibility that races or populations of the nematode exist. Since a recent taxonomic revision of the root-knot nematodes has established the existence of several species, the possibility exists that each may incite a distinctly different pathological response from a specific host. Research reported in this paper involved the use of several root-knot nematode species to determine the effects of these parasites on snapdragon, as well as the effects of the host on the parasites.

REVIEW OF LITERATURE.—Tufts and Day (17) reported that Bokhara, Shalil, and Yunnan peaches grown in soil uniformly infested with root-knot nematodes were not attacked by these pathogens. Later, however, they (8) reported that each of the 3 peach varieties became lightly infected from these nematodes. They found that in growing hundreds of Shalil seedlings in a root-knot nematode infested nursery for 6 years, not 1 plant was attacked by nematodes, yet when the nursery site was changed to a location a mile away, 24 per cent of the Shalil seedlings were attacked. These investigators concluded that different nematodes strains existed at the 2 growing sites.

In experiments attempting to infect Shalil and "natural" peach seedlings using root-knot nematode infested soil from 5 different locations, Clayton (7) found that in soil from 3 orchards Shalil roots remained free from root-knot while 50 to 70 per cent of the "natural" seedlings became infected. Both varieties, however, were equally susceptible to root-knot when grown in soil from orchards where Shalil seedlings were infected. From similar observations various investigators had concluded that the root-knot nematode was comprised of races or strains (4,5,9,13,15,18). Christie and Havis (6) tested several races of the root-knot nematode against varieties of peach trees. From their results, it is shown that individual varieties reacted differently in gall formation when infected with different races of the root knot nematode. Reynolds (12) found that when 3 races of root-knot nematodes were tested in Egyptian and Upland cotton, differences in the mean number of nematode egg masses per plant resulting from the inoculations were all significant at odds of 99 to 1. Christie and Albin (5) stated that plants may be susceptible to 1 race but resistant to another or that plants may be susceptible to each of 2 different races but may differ in the type of root galling produced by 1 race in comparison to that produced by the other. They found that peanut, cotton, and alfalfa were susceptible to some races but resistant to others. In working with tomato, which was equally susceptible to all races, they found that some races produced galls which were small, inconspicuous, and most confined to small roots, large roots near the base of the stem not being appreciably affected. Other races produced galls that developed numerous radiating rootlets which in turn bore galls with radiating rootlets, resulting in a reticulate root system; 1 race caused swelling of all roots, many large galls, and conspicuous absence of fine roots. They concluded that there were probably 5 or more distinct races of the root-knot nematode and that "the possibility that some races may possess distinguishing morphological characters cannot, as yet, be ruled out."

Occurrence of races of the root-knot nematode was an accepted theory when Chitwood (3) separated the root-knot nematodes (formerly *Heterodera marioni* (Cornu, 1879) Goodey, 1932) into 5 distinct species and 1 variety, and revived the generic name *Meloidogyne*. Species of *Meloidogyne* are separated in most cases by distinct morphological characters as well as by differences in pathogenicity for various hosts. *Meloidogyne exigua* Goeldi, 1887, was originally observed on coffee roots in Brazil. *Meloidogyne javanica* (Treub, 1885) Chitwood, 1949, was reported to infect sugar cane in Java. In the United States, this species has been found to infect roots of root-knot susceptible and "resistant" peach varieties as well as several ornamental and vegetable crop plants. *Meloidogyne hapla* Chitwood, 1949, was originally found on the Green Mountain variety of potato but has also been observed to infect strawberries, parsnips, peanuts, and tomatoes. *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949, was first observed in human feces in Texas and other southern states and was thought to have been present in the vegetables eaten. It is regarded as the most common root-knot nematode in a large part of the United States (16), and reproduces on cactus, cotton, celery, lima beans, peppers, and Yellow Globe onions. Taylor and Chitwood (16) report that *Lycopersicon peruvianum* (L.) Mill. is not affected by *M. incognita*. *Meloidogyne incognita* var. *acrita* Chitwood, 1949, closely resembles the parent species in both morphology and pathogenicity, showing slight morphological differences, however, in compari-

[1]Accepted for publication July 15, 1952.

Scientific Article No. A356, Contribution No. 2336 of the Maryland Agricultural Experiment Station, Division of Plant Pathology, College Park, Maryland in cooperation with the Division of Nematology, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Dept. Agriculture, Beltsville, Maryland. Based on a thesis submitted to the Graduate School, University of Maryland, in partial fulfillment of the requirements for the Doctor of Philosophy degree.

[2]Formerly Assistant Nematologist, Division of Nematology, B.P.I.S.A.E., Beltsville, Maryland, now Assistant Research Professor of Plant Pathology, University of Rhode Island, Kingston.

son of perineal regions and shapes of buccal stylet knobs. *Meloidogyne incognita* var. *acrita* may be separated from *M. incognita* in that the former will infect *Lycopersicon peruvianum*, while the latter will not (16). *Meloidogyne arenaria* (Neal, 1889) Chitwood, 1949, was first observed causing extensive damage to peanuts. Although pathogenic to Lovell peach, it reproduces poorly, if at all, on this host.

Snapdragon (*Antirrhinum majus* L.) is regarded as being susceptible to root-knot by Bessey (2), Barrus, et al. (1), Godfrey (10), and Parris (11). There are many cases on record in the Division of Nematology, U. S. Department of Agriculture, Beltsville, Md., in which snapdragon roots have been found to be infected by root-knot nematodes.

Materials and methods.—Nematode inoculum consisted of egg masses of *Meloidogyne arenaria, M. hapla, M. incognita, M. incognita* var. *acrita*, and *M. javanica*. All species were maintained on the Rutgers variety of tomato, *Lycopersicon esculentum* Mill. on which production of egg masses readily occurs. The 3 levels of inoculum employed were 1, 10, and 100 egg masses. The 1 and 10 egg mass inocula were composed of small sections of root tissue[3] in each of which was situated an ovipositing female nematode. In obtaining the 100 egg mass inocula, heavily infected roots bearing numerous egg masses were finely chopped and thoroughly mixed. Egg masses contained in a representative portion of this mixture were then counted under a stereoscopic microscope and the weight of roots containing approximately 100 egg masses was computed. Before any inoculum was selected from an infected plant, several representative egg masses were broken open and the contents checked to ascertain the presence of infectious larvae.

The 5 varieties of snapdragon used were Ball Red Hybrid #7, Christmas Cheer, Margaret, Maryland Pink, and Ball Yellow Hybrid #1. Seedlings were transplanted into 5-inch pots half filled with an autoclaved potting mixture of 1 part sand to 1 part soil. After the inoculum was introduced into each pot and thoroughly mixed into the surface of the soil, the potting mixture necessary to fill each pot was added and the pots were watered.

Due to lack of adequate greenhouse space, plants were grown close to one another. To eliminate the hazard of contamination of treatments from splashing during watering, a spray rig consisting of 8 microjet nozzles was mounted on wires above the bench and used to water the plants.

The experiment was designed to investigate the effect of 5 species of root-knot nematodes at 3 levels of inoculum on 5 varieties of snapdragon. All possible combinations of these variables as well as 1 noninoculated control plant of each snapdragon variety were replicated in each of 5 blocks. Plants were placed in the greenhouse in a split-plot design and grown at an average temperature of 22° C. After 2½ months, data were obtained on top weight of plants (aerial parts), root weight, root-knot index, number of female nematodes, number of egg masses, and rate of nematode reproduction in each plant.

In harvesting, root systems of plants were washed gently in water so that most debris was eliminated. Indexing of infected roots was accomplished using the system proposed by Smith and Taylor (14). In this system of indexing, plants without any visible root infection received a rating 0, those with root systems bearing 1 to 25 per cent infection of the total number of roots received a rating of 1, those with root infections of 26 to 50 per cent received a rating of 2, plants with 51 to 75 per cent of their root systems infected received a rating of 3, and those with root systems bearing 76 to 100 per cent infections received a rating of 4. One-half of the root system of each infected plant was preserved in 5 per cent formaldehyde for future counts of females and egg masses, at which time the roots were washed free of formaldehyde, finely chopped, and thoroughly mixed. Three hundred mg. root samples from all plants originally inoculated with 1 egg mass, 200 mg. samples from plants inoculated with 10 egg masses, and 100 mg. samples from plants inoculated with approximately 100 egg masses were weighed on a torsion balance, caution being exercised so that no sample dried more than did others. Each weighed sample of roots was placed in a shallow layer of water in a Syracuse watch glass and examined for the presence of adult female nematodes and egg masses. Having obtained counts from each sample, values were then computed on the basis of root weight of each plant in order to estimate the total number of females and egg masses per plant. Values for the rate of nematode reproduction for each plant were obtained by dividing the total number of egg masses per plant by the total number of females.

Results.—From Fig. 1, A it is apparent that while there were no significant differences between top weights of plants infected with different species of *Meloidogyne*, an increasingly greater amount of inoculum resulted in significantly lower top weights. Some varieties of *Antirrhinum* infected with nematodes had significantly higher top weights than did others. When top weights of noninoculated snapdragon controls were compared with those of inoculated plants, it was seen that noninfected plants of all varieties, except Ball Yellow, grew more vigorously than did infected plants. The reason for the failure of noninoculated Ball Yellow plants to grow more vigorously than did inoculated plants of the same variety is not known.

Root weights of plants infected with *M. arenaria* and *M. javanica* were significantly lower than were root weights of plants infected by the other 3 species (Fig. 1, B). Whereas there were no significant differences in root weights between plants receiving the 1 and 10 egg mass inocula, plants inoculated with 100 egg masses had significantly lower root weights than did plants receiving lesser amounts of inoculum. The

[3]Pieces of infected root tissue were used instead of isolated egg masses, to insure collection of all of the eggs that had been deposited by each female.

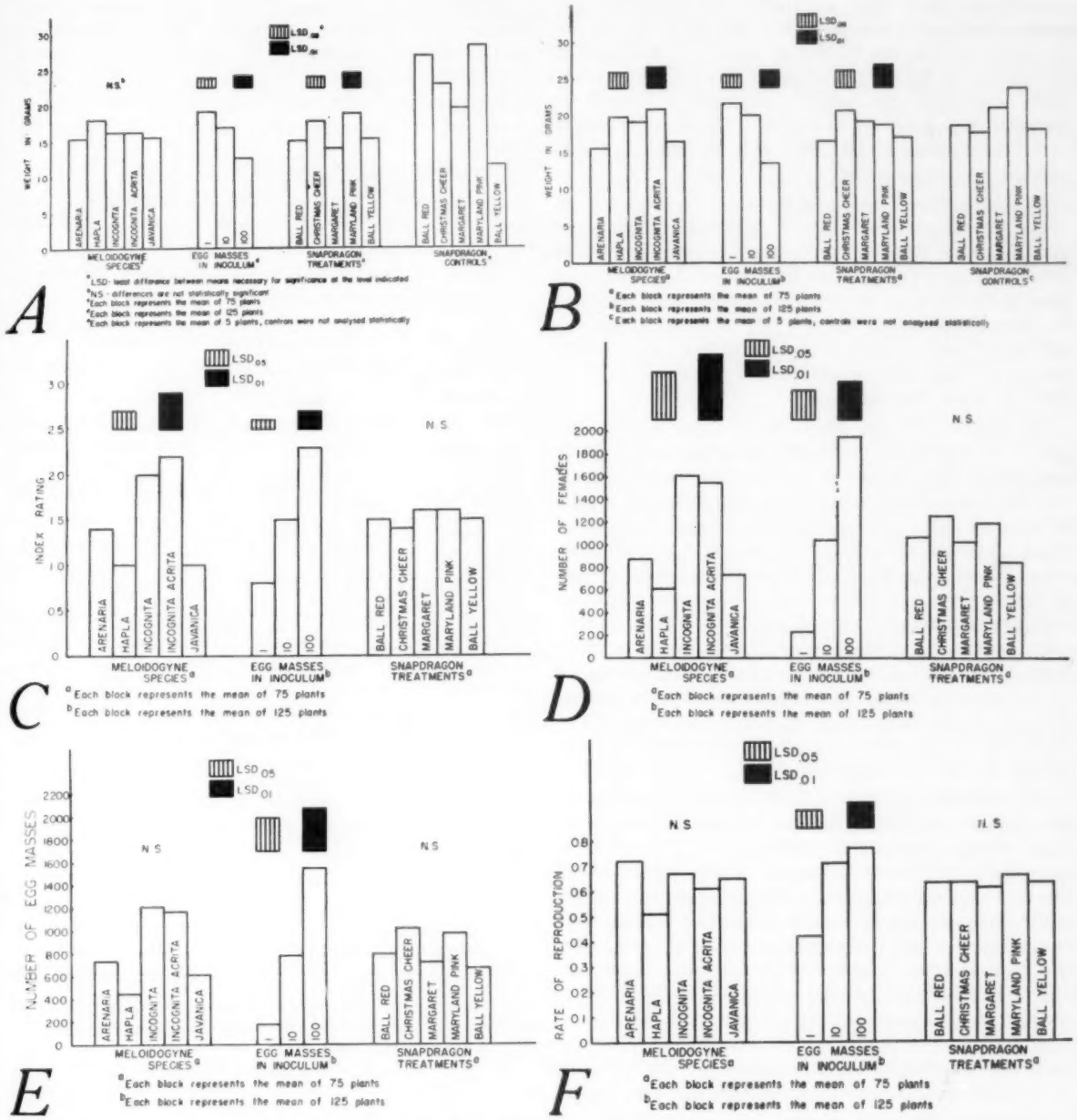


FIG. 1. Effect of *Meloidogyne* species and levels of inoculum on 5 snapdragon varieties: A) Top weight; B) Root weight; C) Root-knot index; D) Number of females; E) Number of egg masses; F) Rate of nematode reproduction.

Christmas Cheer variety of snapdragon formed significantly heavier root systems when bearing nematode infections than did either the Ball Red or Ball Yellow varieties. All noninoculated plants, except Christmas Cheer, formed heavier root systems than did inoculated plants.

Differences in degree of galling between plants infected by different root-knot nematode species are shown in Fig. 1, C. Root-knot indexes of plants infected by *M. incognita* and *M. incognita* var. *acrita*, while not differing significantly from each other, were significantly higher than they were for plants infected by other species. Plants infected by *M. arenaria* had a higher index rating than did *M. hapla*- and *M. javanica*-infected plants. As the level of inoculum increased root-knot indexes became increasingly greater.

The number of female nematodes was significantly higher in roots of plants infected by *M. incognita* and *M. incognita* var. *acrita* than in plants infected by the other 3 *Meloidogyne* species (Fig. 1, D). There was a direct correlation between the amount of inoculum applied and the resulting number of females.

Although there were no significant differences between numbers of egg masses produced on plants infected by each of the *Meloidogyne* species, the amount of oviposition by each species (Fig. 1, E) was strikingly similar to the number of females formed as shown in Fig. 1, D. As in Fig. 1, D, there was a direct correlation between the amount of inoculum applied and the resulting number of egg masses.

In Fig. 1, F are compared the rates of reproduction of the various nematode species. Although results were not significant in this experiment, a second experiment conducted on a comparable basis showed *M. hapla* to have a significantly lower reproductive rate than did 3 other *Meloidogyne* species. Of interest is the significantly lower rate of nematode reproduction resulting from 1 egg mass inoculation as compared to 10 to 100 egg mass inoculations.

Discussion.—It has been shown from results presented in this paper that valid differences exist in the reaction of snapdragons to infection by each species of root-knot nematodes used. Root weights of *M. hapla*-infected plants were significantly higher than were those of plants infected by *M. arenaria* and *M. javanica*. Plants infected by *M. hapla* had a lower number of females and egg masses and a lower rate of nematode reproduction, than did plants infected by most other species. *Meloidogyne hapla* was shown to differ from other species by the root-knot index rating of plants infected by it. This rating was invariably quite low. A close inspection of *M. hapla*-infected root systems showed that galls were spherical, small, and produced abundant lateral rootlets.

Meloidogyne incognita and *M. incognita* var. *acrita* were somewhat similar in their overall effects on the host. However, significant differences between them were indicated, in several cases, by the statistical analyses which revealed interactions of nematode species with inoculum levels and of nematode species with snapdragon varieties. Separation of the 2 varieties on the basis of type or size of galls formed was not possible; both form numerous elongate, fleshy galls as well as an abundance of smaller spherical galls.

Meloidogyne arenaria, in comparison with other species, was found to be intermediate in its pathogenicity for snapdragon. Plants infected with this species had significantly lower root weights than did those infected by *M. hapla*, *M. incognita*, and *M. incognita* var. *acrita*. Whereas the root-knot index rating of plants infected by *M. arenaria*, as well as number of females and egg masses formed, was lower than for *M. incognita* and *M. incognita* var. *acrita*, these values were higher than for *M. hapla*- and *M. javanica*-infected plants. *Meloidogyne arenaria* had a higher rate of nematode reproduction (total number of egg masses per plant divided by the total number of females per plant) than did other species. Root galls formed by this species were more or less intermediate in size between galls formed by *M. incognita* and those formed by *M. hapla*. Both the spherical and the elongate, somewhat fleshy galls were formed by this species.

Meloidogyne javanica behaved in a fashion similar to that of *M. hapla* except that its rate of reproduction was considerably higher. Galls formed by this species were somewhat similar in appearance to *M. arenaria* galls, being both the spherical type and the elongate, multiple-infection type (the former being more numerous).

All of the *Meloidogyne* species used were capable of infecting each of the 5 varieties of snapdragon. It was possible to differentiate between species on the basis of measurements of the pathological response of snapdragons to infection and, to some extent, by the difference in developmental behavior of species.

Summary

A recent revision of the classification of root-knot nematodes into 5 species and 1 variety necessitated a study of the effects of these species on a suitable host, the common snapdragon, *Antirrhinum majus*. Plants infected by *Meloidogyne arenaria* and *M. javanica* formed smaller root systems than plants infected by other species of Meloidogyne. The root-knot index rating for *M. arenaria*-infected plants, however, was higher than for *M. javanica*-infected plants. Plants infected by *M. hapla* also had a low root-knot index rating but this species formed galls that were spherical and small in comparison to galls formed by other species. *Meloidogyne incognita* and *M. incognita* var. *acrita* formed a greater number of females per unit of inoculum than did other species of *Meloidogyne*. The root-knot index rating of plants infected by this species and its variety was higher than for plants infected by other species.

Division of Nematology
Plant Industry Station
Beltsville, Maryland

Literature Cited

1. Barrus, M. F., O. C. Boyd, and J. I. Wood. 1931. Diseases of plants in the United States in 1930. U. S. Dept. Agr. Pl. Dis. Rptr. Supp. **81**: 30-135.
2. Bessey, E. A. 1911. Root-knot and its control. U. S. Dept. Agr., Bur. Pl. Ind. Bul. 217.
3. Chitwood, B. G. 1949. "Root-Knot Nematodes"—Part I. A revision of the genus Meloidogyne Goeldi, 1887. Proc. Helm. Soc. Wash. **16**: 90-104.
4. Christie, J. R. 1946. Host-parasite relationships of the root-knot nematode, Heterodera marioni. II. Some effects of the host on the parasite. Phytopathology **36**: 340-352.
5. Christie, J. R., and F. E. Albin. 1944. Host-parasite relationships of the root-knot nematode, Heterodera marioni. I. The question of races. Proc. Helm. Soc. Wash. **11**: 31-37.
6. Christie, J. R., and L. Havis. 1948. Relative susceptibility of certain peach stocks to races of the root-knot nematode. U. S. Dept. Agr., Pl. Dis. Rptr. **32**: 510-514.
7. Clayton, C. N. 1947. Roots of Shalil peach seedlings are not resistant to all races of the root-knot nematode. U. S. Dept. Agr., Pl. Dis. Rptr. **31**: 153-154.
8. Day, L. H. and W. P. Tufts. 1939. Further notes on nematode-resistant root stocks for deciduous fruit trees. Proc. Amer. Soc. Hort. Sci. **37**: 327-329.
9. Day, L. H. and W. P. Tufts. 1944. Nematode-resistant root stocks for deciduous fruit trees. Calif. Agr. Exp. Sta. Cir. **359**: 1-16.

10. GODFREY, G. H. 1935. Herbaceous ornamentals heavily infested by Heterodera marioni (Cornu) Goodey. U. S. Dept. Agr. Pl. Dis. Rptr. **19**: 274.
11. PARRIS, G. K. 1940. A check list of fungi, bacteria, nematodes, and viruses occurring in Hawaii and their hosts. U. S. Dept. Agr., Pl. Dis. Rptr. Suppl. **121**: 1-90.
12. REYNOLDS, H. W. 1949. Relative degree of infection of American-Egyptian and upland cotton by three populations of the root-knot nematode. U. S. Dept. Agr. Pl. Dis. Rptr. **33**: 306-309.
13. SHERBAKOFF, C. D. 1939. Root-knot nematode on cotton and tomatoes in Tennessee. (Abs.) Phytopathology **29**: 751-752.
14. SMITH, A. L. AND A. L. TAYLOR. 1947. Field methods of testing for root-knot infestation. Phytopathology **37**: 85-93.
15. TAYLOR, A. L. 1944. Root-knot on Shalil and Yunnan peach seedlings. Twenty-fourth Annual Report, Georgia Coastal Plains Exp. Sta. Bul. **40**: 112.
16. TAYLOR, A. L. AND B. G. CHITWOOD. 1951. Root-knot susceptibility of Lycopersicon peruvianum. U. S. Dept. Agr., Pl. Dis. Rptr. **35**: 97.
17. TUFTS, W. P., AND L. H. DAY. 1934. Nematode resistance of certain deciduous fruit tree seedlings. Proc. Amer. Soc. Hort. Sci. **31**: 75-82.
18. WILSON, C. 1948. Root-knot nematodes on peanuts in Alabama. U. S. Dept. Agr., Pl. Dis. Rptr. **32**: 443.

COMPARATIVE STUDIES OF SOME ROOT-KNOT NEMATODES INFECTING THE COMMON SNAPDRAGON, ANTIRRHINUM MAJUS L.[1]

A. C. Tarjan [2]

Literature on the life history of the root-knot nematode has been based on the assumption that root-knot nematodes belonged to a single species (1, 2, 6, 8, 9, 10, 11). Such work, although not invalidated by Chitwood's classification of the root-knot nematode into 5 distinct species and 1 variety and revision of the genus *Meloidogyne* (3), now needs further clarification as to which species or mixture of species investigators dealt with.

MATERIALS AND METHODS.—Root-knot nematode species used in the present study were *Meloidogyne arenaria* (Neal, 1889) Chitwood, 1949, *M. hapla* Chitwood, 1949, *M. incognita* (Kofoid and White, 1919) Chitwood, 1949, *M. incognita* var. *acrita* Chitwood, 1949, and *M. javanica* (Treub, 1885) Chitwood, 1949. Seedlings of the Margaret variety of common snapdragon were transplanted into 3-in. pots filled with a sterilized potting mixture of 2 parts sand to 1 part soil. After several days, during which time plants had become established, 5 egg masses of 1 of the *Meloidogyne* species were placed in each pot. This was repeated for each of the other species so that plants were exposed to separate infections by each of the *Meloidogyne* species used. There were 30 replicate plants inoculated within each species or variety. Two days after inoculation and at 2-day intervals thereafter, part of the root system of a plant from each series was removed and stained. Since egg masses within the inoculum were continuously discharging infectious larvae for a considerable period, it was necessary to study, in each case, the oldest established infections observed in the stained roots. During this experiment the average soil temperature in the greenhouse was 20.4° C.

The staining technique employed for demonstrating presence of root-knot nematodes was suggested by H. W. Reynolds.[3] The fixing and staining solution (6 cc. of distilled water, 10 cc. of 1 per cent chromic acid, 10 cc. of 10 per cent acetic acid, and 2 cc. of 2 per cent osmic acid) was heated to approximately 55° C. Roots were stained in this solution for about 1½ hours after which they were washed in running water for 3 hours. They were then immersed in 15 per cent ethyl alcohol for 15 minutes, 30 per cent for 30 minutes, 50 per cent for 1 hour, 70 per cent for overnight, 80 per cent for 2 hours, 95 per cent for 2 hours, and absolute alcohol for 2 hours. The dehydrated roots were cleared overnight in methyl salicylate (synthetic oil of wintergreen). Permanent mounts of root pieces were made using Canada balsam as the mounting medium.

RESULTS.—Although each nematode species varied somewhat in time required to reach a certain stage of development, no great differences were observed with respect to their shape or behavior at various stages of their life cycles. Data on occurrence of molts and frequency of occurrence of males was not obtained, since the staining technique used precluded accurate observation of these details.

It was found, in the majority of cases, that second stage infectious larvae penetrated the rootlet at the root tip or in the region of elongation behind the root tip. Once having penetrated the root, larvae usually took a position parallel to the longitudinal axis of the root. Roots examined 2 days after inoculation showed that larvae were not oriented consistently within the roots. Most larvae were found with their heads nearest the root cap while their bodies extended back toward the older tissues; however, others were oriented in the opposite direction. Larvae were not always observed with their bodies parallel to the longitudinal axis of the root but were, on several occasions, curled

[1] Accepted for publication July 21, 1952.
Scientific Article No. A355, Contribution 2335, of the Maryland Agricultural Experiment Station, Division of Plant Pathology, College Park, Maryland, in cooperation with the Division of Nematology, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture, Beltsville, Maryland. Based on a thesis submitted to the Graduate School, University of Maryland in partial fulfillment of the requirements for the Doctor of Philosophy degree.

[2] Formerly Assistant Nematologist, Division of Nematology, B.P.I.S.A.E., Beltsville, Maryland, now Assistant Research Professor of Plant Pathology, University of Rhode Island, Kingston.

[3] Associate Nematologist, Division of Nematology, U. S. Field Station, Sacaton, Arizona.

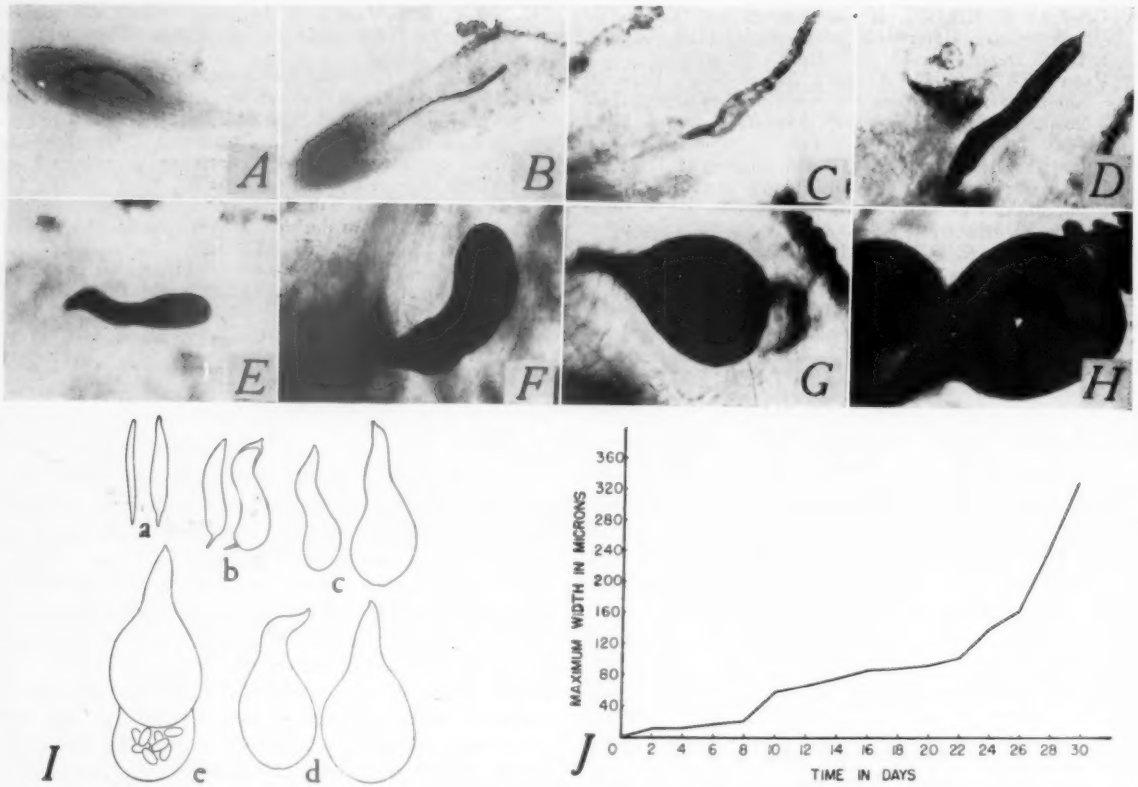


FIG. 1. A-H, Various stages of *Meloidogyne* species in snapdragon roots. × 100. A) A larva of *M. javanica* 2 days after inoculation. B) A larva of *M. incognita* var. *acrita* 4 days after inoculation. Note the inception of gall formation. C) Second-stage larva of *M. hapla* 10 days after inoculation showing partial thickening of the body immediately posterior to the esophageal region. D) A spindle-shape larva of *M. hapla* 18 days after inoculation. Note the presence of the tail. E) Developing larva of *M. javanica* 20 days after inoculation. Note the absence of a tail. F) Larva of *M. javanica* 24 days after inoculation showing increase in body width. G) A gravid female of *M. incognita* 30 days after inoculation. Note the gelatinous matrix, the formation of which always precedes oviposition, at the posterior end of the animal. H) An ovipositing female of *M. incognita* var. *acrita*. I) Groups a through e into which the nematodes were classified according to the amount of development undergone (after Christie). J) Mean growth curve of root-knot nematodes as determined by maximum increase in width.

within the root tip (Fig. 1, A). As the root meristems grew beyond the sites of larval penetration, larvae oriented themselves by the fourth day to a position with their heads embedded in the outer tissues of the stele and their bodies in the tissues of the cortex extending downward toward the root tip. Early gall formation was noticed in several rootlets indicating that lateral growth of infected areas must have started within 2 to 4 days after inoculation. Figure 1, B shows early gall formation in a root parasitized by a larva of *M. incognita* var. *acrita*.

Sections of roots which bore heavy infections of root-knot nematodes were not uncommon. Root tips inhabited by large numbers of parasites were usually stunted, with gall formation quite evident. This has also been observed by Godfrey and Oliveira (7) in their studies of root-knot nematode infections of pineapple roots.

Nematodes increased slowly in width until between the eighth and tenth day after inoculation, when rapid increases occurred. Widening of the body, in most cases, was uneven and irregular. Usually the region of the body directly posterior to the base of the esophagus increased in width first (Fig. 1, C). Immediately thereafter, the posterior third of the body widened, with the middle of the body and the esophageal region increasing in width last. During this period of growth, the tail of the animal remained unchanged, resulting in a "spiked" appearance of the posterior part of the body (Fig. 1, D). In swelling, the esophageal area of the body went through a greater increase in width near the base of the esophagus and a lesser increase at the head, resulting in a tapered appearance of the body from the base of the esophagus to the head. Of decided interest was the appearance of heavily stained cells of the stele around the heads of the parasites about 8 to 10 days after inoculation (Fig. 1, C, D). This indicated that formation of giant, multinucleate cells (5) had been stimulated by the parasites, and had become filled with protoplasm which stained densely.

About 10 to 14 days after inoculation, nematodes of most species were spindle-shaped (Fig. 1, D). Fol-

lowing the occurrence of the 3 molts described by Christie and Cobb (6), parasites were observed as young females of the typical shape shown in Fig. 1, E. The posterior region of the female body increased in width, as did the anterior region of the body shortly thereafter. About 24 days after inoculation, there was a rapid increase in width as well as length of females (Fig. 1, F). Nematodes examined 26 days after inoculation were almost fully grown. In most cases, a gelatinous matrix was exuded by females from 28 to 30 days after inoculation (Fig. 1, G). As a rule the formation of this matrix preceded oviposition by as much as 2 days. Figure 1, H shows a female of *M. incognita* var. *acrita* with a number of newly formed eggs.

Whereas females of *Meloidogyne arenaria*, *M. hapla*, and *M. incognita*, oviposited 30 days after inoculation of roots, oviposition by *M. incognita* var. *acrita* and *M. javanica* was not observed. Presumably the Margaret variety of snapdragon was not a suitable host for these latter species under conditions of this experiment.

Periodic checks of plants revealed that eggs had hatched and that second generation larvae had entered root tips 66 days after inoculation in the case of *M. arenaria* and 68 days after inoculation for *M. hapla*. Infection of root tips by second generation larvae of *M. incognita* was not observed.

Christie (4) grouped the root-knot nematodes into 5 categories on the basis of their shapes during development (Fig. 1, I). Larvae from the stage at which they had begun to grow to the stage at which they still possessed a more or less conical tail were put in Group A (Fig. 1, I, a). Group B included larvae from the stage at which they had acquired a more or less hemispherical posterior end terminated by a spike to a stage at which they were about to complete the final molt (Fig. 1, I, b). Group C included females from the stage at which they had completed the final molt to the stage at which they were almost fully grown (Fig. 1, I, c). Group D included females that were fully grown or almost fully grown but had not yet laid eggs (Fig. 1, I, d). Group E included ovipositing females (Fig. 1, I, e).

Stages of development of the root-knot nematodes on snapdragon are compared, using Christie's groupings, in Table 1.

TABLE 1. *Comparison of stages of development of the root-knot nematodes on snapdragon.*

Stage of Development[a]	*Meloidogyne* species				
	arenaria	*hapla*	*incognita*	*incognita acrita*	*javanica*
Group A	2-8[b]	2-10	2-8	2-8	2-8
Group B	10-12	12-16	10	10	10-12
Group C	14-22	18-26	12-22	12-26	14-26
Group D	24-28	28	24-28	28-30	28-36
Group E	30	30	30	....[c]	....

[a] Refer to Fig. 1, I.
[b] Days after inoculation.
[c] Ovipositing females were not observed.

TABLE 2. *Comparison of stages of development of the root-knot nematodes in snapdragon and tomato*

Host	*Meloidogyne* Species	Gelatinous Matrix Produced	Egg Production	Infection by second generation larvae
Tomato	*arenaria*	37[a]	39	63
	hapla	37	39	63
	incognita	37	39	57
	incognita acrita	37	37	59
	javanica	35	39	63
Snapdragon	*arenaria*	28	30	66
	hapla	28	30	68
	incognita	30	30	....[b]
	incognita acrita	30	....	....
	javanica	36	....	....

[a] Days after inoculation of plants.
[b] Not observed.

During examination of the nematodes throughout this experiment, record of the maximum nematode width was kept for each species at each sampling date. Curves plotted for each species failed to reveal any outstanding differences between species; therefore a mean curve was plotted which is representative of all 5 species (Fig. 1, J). It shows that the greatest increase in width occurred during periods of 8 to 10, and 22 to 30 days after inoculation.

Having observed details of the life histories of some *Meloidogyne* species on snapdragon, it was thought advisable to investigate the more important details of the development of these nematode species on tomato, *Lycopersicon esculentum* Mill. hort. var. Rutgers. Several month-old seedlings were transplanted into 4-in. pots containing soil well infested with each type of inoculum so that plants were exposed to separate infections. Greenhouse soil temperatures averaged 21° C. during this experiment. Examinations revealed that females of *M. javanica* produced the gelatinous matrix preceding oviposition 35 days after inoculation of plants. Females of the other 4 species produced this matrix by the 37th day after inoculation. *Meloidogyne incognita* var. *acrita* females produced eggs in the gelatinous matrix 37 days after inoculation, while females of the other species produced eggs by the 39th day after inoculation. Continued examinations showed that penetration of root tips by second generation larvae of *M. incognita* occurred 57 days after inoculation, of *M. incognita* var. *acrita* 59 days after inoculation, and of the other 3 species 63 days after inoculation. A comparison of these results with those obtained with snapdragon are presented in Table 2.

DISCUSSION OF RESULTS.—Studies on life histories of root-knot nematodes indicated that there were no basic, outstanding differences between them in regard to their development on snapdragon. Ovipositing females of *M. incognita* var. *acrita* and *M. javanica* were not observed (Table 1). Failure of females of these 2 species to form eggs was extremely enigmatic in view of the fact that all species had readily oviposited in previous tests. Christie (4), in a paper on the effects

of the host on root-knot nematodes, presented several facts which aided in explaining the abnormal behavior of *M. incognita* var. *acrita* and *M. javanica* in the present studies. Christie tried to maintain root-knot nematodes on tomato by repeated inoculations and found that subsequent infections became less severe. Attempts to maintain populations from single egg masses, in some cases, resulted in the formation of a correspondingly fewer number of egg masses.

Christie concluded that retarded development of the host was an indication of unsuitability and that there was no correlation between the suitability of a host and the freedom with which larvae penetrated its roots. He did find a direct correlation between suitability of the host and the rate of parasite development and a direct correlation between rate of parasite development and egg production. When development was strongly retarded many of the females never reached maturity and there was a reduction in the egg output of those that did; in extreme cases development was almost completely suppressed. Unsuitability of the host did not necessarily reduce the severity of galling.

Inoculum used for life cycle studies of nematodes on snapdragon was obtained from snapdragon and correspondingly both *M. incognita* var. *acrita* and *M. javanica* apparently failed to reproduce on snapdragon, which had become an undesirable host. Additional attempts to infect snapdragons with larvae of these 2 species likewise demonstrated the unsuitability of the plant as a desirable host for subsequent generations of these 2 species. Although usually no difficulty was encountered in obtaining larval penetration of root tips when snapdragons were used repeatedly as host plants, these plants failed to grow properly and their root systems soon became predominantly necrotic. Inspection of such roots in several cases showed the presence of decayed galls. A further indication that unsuitability of the snapdragons used in these life cycle studies was responsible for lack of fecundity in *M. incognita* var. *acrita* and *M. javanica* was also demonstrated by the fact that tomato plants became heavily infected when placed in infested soil in which snapdragons either failed to grow or grew poorly. Each of the *Meloidogyne* species infecting the tomato plants formed numerous egg masses (Table 2). It was found that species of *Meloidogyne* have a shorter life cycle and have more generations when infecting snapdragon than when infecting tomato.

SUMMARY

A study of the life history of 4 species and 1 variety of *Meloidogyne* infecting the Margaret variety of snapdragon, *Antirrhinum majus* failed to reveal any outstanding differences between species. A failure of *M. incognita* var. *acrita* and *M. javanica* to reproduce was attributed to the fact that inoculum for this experiment had been obtained from snapdragon. Use of the same host plant for successive generations of nematodes was believed to have caused a failure in reproduction of these species due to the unsuitability of snapdragon as a host. It was shown that females of *M. arenaria*, *M. hapla*, and *M. incognita* oviposited 30 days after the plants were inoculated. Infection of root tips by second generation larvae was detected 66 days after inoculation for *M. arenaria* and 68 days after inoculation for *M. hapla*. When tomato seedlings were placed in soil infested by each of the 4 nematode species and 1 variety, *M. incognita* var. *acrita* developed eggs in 37 days while the rest of the *Meloidogyne* species required 39 days for oviposition. Infection of tomato roots by the second generation larvae occurred 57 days after inoculation for *M. incognita*, 59 days after inoculation for *M. incognita* var. *acrita*, and 63 days after inoculation for *M. arenaria*, *M. hapla*, and *M. javanica*.

DIVISION OF NEMATOLOGY
PLANT INDUSTRY STATION
BELTSVILLE, MARYLAND

LITERATURE CITED

1. ATKINSON, G. F. 1890. Nematode root-galls. A preliminary report on the life history and metamorphoses of a root-gall nematode, Heterodera radicicola (Greeff) Müll., and the injuries produced by it upon the roots of various plants. Jour. Elisha Mitchell Sci. Soc. **6**: 81-130.
2. BESSEY, E. A. 1911. Root-knot and its control. U. S. Dept. Agr., Bur. Pl. Ind. Bul. 217, 89 pp.
3. CHITWOOD, B. G. 1949. "Root-Knot Nematodes"—Part I. A revision of the genus Meloidogyne Goeldi, 1887. Proc. Helm. Soc. Wash. **16**: 90-104.
4. CHRISTIE, J. R. 1946. Host-parasite relationships of the root-knot nematode, Heterodera marioni. II. Some effects of the host on the parasite. Phytopathology **36**: 340-352.
5. CHRISTIE, J. R. 1936. The development of root-knot nematode galls. Phytopathology **26**: 1-22.
6. CHRISTIE, J. R. AND G. S. COBB. 1944. Notes on the life history of the root-knot nematode, Heterodera marioni. Proc. Helm. Soc. Wash. **8**: 23-26.
7. GODFREY, G. H. AND J. OLIVEIRA. 1932. The development of the root-knot nematode in relation to root tissues of pineapple and cowpea. Phytopathology **22**: 325-348.
8. NAGAKURA, K. 1930. Ueber den bau und die Lebensgeschichte der Heterodera radicicola (Greeff) Müller. Jap. Jour. Zool. **3**: 95-160.
9. SANDGROUND, J. H. 1922. A study of the life history and methods of control of the root gall nematode, Heterodera radicicola (Greef Muller), in South Africa. So. Afr. Jour. Sci. **18**: 399-418.
10. TYLER, J. 1933. Development of the root-knot nematode as affected by temperature. Hilgardia **7**: 391-415.
11. TYLER, J. 1933. The root-knot nematode. Calif. Agr. Exp. Sta., Berkeley Circ. 330, 34 pp.

VARIATION IN PATHOGENICITY AMONG ISOLATES OF PHYTOPHTHORA INFESTANS ON TOMATO AND POTATO[1]

Paul E. Waggoner and J. R. Wallin[2]

In the North Central Region of the United States, *Phytophthora infestans*, the causal agent of potato and tomato late blight, has appeared to some extent each year since 1941. One reason might be that more virulent strains of the pathogen have developed in the tomato and potato areas. Perhaps strains pathogenic on the tomato were occurring commonly on the potato. To test this hypothesis, isolates of the pathogen were collected from tomato and potato within the region and were cross-inoculated onto each of these hosts.

Variation in the pathogenicity of *Phytophthora infestans* has been demonstrated in earlier work reviewed elsewhere (2, 9, 11). Also, the variability in susceptibility of the host, i.e., potato, potato hybrids, and tomato, to certain isolates of the pathogen has been recognized (9, 10, 11, 12). Furthermore, temperature and humidity fluctuations have been shown to influence late blight development (1, 8).

Although there were numerous studies dealing with variation in the factors influencing disease, before experimentation was undertaken the effects attributable to each factor had to be clearly defined. Then quantitative data could be employed.

First, expression or quantity of disease on the host is stated to be a function[3] of 4 factors, i.e., host, pathogen, environment, and time. Then 4 types of pathogen variants or races are defined in terms of quantity of disease. First, if isolates differ significantly in the average quantity of disease they produce on all hosts, under all environments, and after all times of development employed in the experiment, the isolates are called *pathic* races. Second, if isolates cause quantities of disease which are significantly differential for host-pathogen combinations averaged over all environments and times of development employed in the experiment, the isolates are called *hostic* races. In the analysis of variance hostic races will be identified by a significant mean square for the interaction of host and pathogen. Third, if isolates cause quantities of disease which are significantly differential for pathogen-environment combinations averaged over all hosts and times of development employed in the experiment, the isolates are called *environmental* races. Environmental races will be identified by a significant mean square for the interaction of environment and pathogen. Fourth, if isolates cause quantities of disease which are significantly differential for pathogen-development time combinations averaged over all hosts and environments employed in the experiment, the isolates are called *developmental* races. Developmental races will be identified by a significant mean square for the interaction of pathogen and time of development. Significant higher order interactions will indicate that the expression of one of these races is affected by one or two of the other factors.

Examples of the 4 different kinds of races can be found in the literature. Both pathic and hostic races have been observed in *Gibberella saubinetti* (3). Strains of *Phytophthora infestans* that are capable of surviving high temperatures (7) constitute environmental races. A developmental race of *Puccinia triticina* has been discriminated by its long incubation period (6). Manifestations of the races have been shown to be affected by other factors. For example, manifestation of hostic races of *Ustilago kolleri* depends upon the environment (5).

The definitions proposed integrate past studies in variation of pathogens. The definitions are precise and permit the use of quantitative experimental evidence. For these reasons they are employed in the present studies in variation of *Phytophthora infestans*. Of course, the definitions are general and can be used to design and analyze a wide variety of experiments in pathology.

ISOLATES.—Isolates T'1, T'2, and T'4 were obtained from tomato plants in Indiana tomato growing regions. T'3 was obtained from potatoes growing in a home garden adjacent to a severely blighted Indiana tomato field. M'1 was isolated from potatoes in Florida, and M'2 and M'3 from potatoes in Indiana. M'4 was isolated from tomato fruit in a plot where potatoes had been inoculated with P'1. P'1, P'2, and P'4 were isolated from potatoes in primarily potato growing regions, N. Dakota and Wisconsin. P'2 is Mill's (9) potato culture.

The isolates were cultured on a medium of soybeans, dextrose, and agar. Cultures from which inoculum was taken had been transferred less than 15 days before inoculation.

EFFECT OF ENVIRONMENT AND TIME UPON GREEN-

[1]Accepted for publication August 5, 1952.
Journal Paper No. J-2089 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project 1163. Part of a thesis submitted by the senior author to the Graduate Faculty of the Iowa State College in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with additional data supplied by the junior author.
This study was conducted under the Research and Marketing Act of 1946 in cooperation with the Iowa and Purdue Agricultural Experiment Stations.

[2]Respectively, Assistant Plant Pathologist, The Conn. Agr. Exp. Station, formerly Agent, Division of Mycology and Disease Survey, and Pathologist, Division of Mycology and Disease Survey, U.S.D.A.

[3]The mathematical function relating quantity of disease, e.g., number of leaves infected, to the 4 factors is approximated by a Taylor's expansion about the mean. The resulting equation states that quantity of disease is equal to the mean amount for the experiment plus the main effects and interactions of the 4 factors. After defining words used in pathology in terms of these effects and interactions, an analysis of variance of suitably transformed data provides a test of whether or not there is quantitative evidence for the existence of the defined characteristics.

HOUSE TEST RESULTS.—Effects of environment and time of observation upon manifestation of races were evaluated by inoculating Rutgers tomato and Cobbler potato plants having 25 to 45 and 24 to 50 leaflets, respectively. P'1 and T'3 were used. Two variations in environment were examined. First, sporangial and zoosporal suspensions of both isolates were sprayed onto 4 tomato and 4 potato plants. Second, half of the plants were placed in a moist chamber for 10 and half for 20 hours, then removed to the greenhouse bench. The percentage of leaflets killed by *P. infestans* was determined 112 and 232 hours after inoculation. The experiment was repeated 3 weeks later. Thus 128 observations were available for analysis after both experiments. Air temperature in the moist chamber was 60 to 80° F. and on the bench 55 to 85° F. During both experiments relative humidity on the bench was above 80 per cent less than 5 hours.

The 128 percentages were transformed into angles (14) after which they were analyzed. The manifestations of any pathic or hostic races are evident in the following table summarizing the 128 observations from the 2 experiments.

Host	Isolate		Mean
	P'1	T'3	
Tomato (T)	24	69	46
Potato (P)	26	15	21
Mean	25	42	33

The difference between the 2 isolates, manifestation of pathic races, was variable and, hence, not significant. On the other hand, the interaction between host and pathogen, manifestation of hostic races, was consistent from replicate to replicate, and, hence, significant. T'3 consistently caused more disease on tomato but not on potato. The consistency of the manifestation of hostic relative to pathic races bears out the statement of Reddick and Crosier (12) that the latter was a temporary characteristic and not evidence of "pathogenic" races.

The effect of inoculum suspension upon manifestation of hostic races can be seen in a different classification of the above data. Each figure is the mean of 16 observations.

Host	Suspension			
	Sporangial Isolate		Zoosporal Isolate	
	P'1	T'3	P'1	T'3
T	31	80	17	58
P	41	21	11	8

The analysis of variance showed that the interaction of host, pathogen, and inoculum suspension is significant. In other words, manifestation of hostic races was more pronounced when a sporangial rather than zoosporal suspension of inoculum was used.

When the inoculated plants remained in the moist chamber 20 rather than 10 hours, the percentage of leaflets killed was increased but the effects of host, pathogen, or inoculum suspension were not altered significantly. Therefore, there was no evidence of environmental races or of an effect of these environments (time in moist chamber) upon hostic races.

Effect of observation time upon manifestation of hostic races can be seen in the following table.

Host	Observation time (hrs. after inoculation)			
	112		232	
	Isolates		Isolates	
	P'1	T'3	P'1	T'3
T	19	51	30	87
P	11	0	40	29

The analysis of variance showed that the interaction of host, pathogen, and time is significant. In other words, manifestation of hostic races was more pronounced when the amount of disease was measured 232 rather than 112 hours after inoculation. This observation, which is consistent with others (4), demonstrates the difference that exists between the 2 hostic races. The "potato" race, P'1, had killed a number of lower tomato leaflets after 112 hours but its further development on tomato was slower than the development of the "tomato" race, T'3. Because development of T'3 was more rapid, on the average, on both hosts, there was a significant interaction of pathogen and time. This can be taken as evidence that the isolates are developmental races. However, because their development on potato was identical, it is more realistic to say that the 2 isolates are hostic races whose manifestations are effected by time of observation.

Effect of observation time upon manifestation of the hostic races was modified significantly by inoculum suspension and by the number of hours in the moist chamber. This occurred in spite of the fact that, on the average, manifestation of hostic races was not modified by number of hours in the moist chamber.

Results show that the most pronounced manifestation of hostic races occurred when a sporangial suspension of inoculum was used and plants were observed 232 hours after inoculation.

GREENHOUSE ASSAY FOR RACES.—The 12 isolates described above were assayed for races. Four of the isolates, T', were obtained from regions where few potatoes were grown; 4, M', where both potatoes and tomatoes were grown; and 4, P', where few tomatoes were grown. Two Rutger tomato and 2 Triumph potato plants with 19 to 36 and 11 to 45 leaflets, respectively, were inoculated by spraying with sporangial suspensions of each of the 12 isolates. The plants were then placed in a moist chamber for 24 hours before being placed on the greenhouse bench. After 112 and 232 hours percentages of leaflets killed by *P. infestans were* determined. The experiment was repeated 3 times. Thus 12 times 2^3 times 3 or 288 observations were available for analysis. Air temperatures in the chamber and on the bench were 50 to 80° F. Relative humidity on the bench was below 80 per cent except for short periods.

Manifestations of any pathic or hostic races can be

seen in the following table summarizing the transformed percentages of leaflets killed in the 3 trials of the experiment. Each of the 6 figures in the body of the table is the mean of 48 observations.

	Isolate Category			
Host	T′	M′	P′	Mean
T	80	45	40	55
P	49	52	55	52
Mean	65	48	47	53

According to an analysis of variance there is evidence that 2 hostic races exist: the tomato race typified by the T′ isolates is severely pathogenic on tomato while the potato race typified by the P′ isolates is less pathogenic on tomato. The two hostic races are not significantly different in their pathogenicity on potato. No significant difference exists between the M′ and P′ isolates. Once again, differences among pathogens averaged overall hosts, manifestations of pathic races, were variable and not significant.

Isolates within the T′ category were uniform in their tomato race behavior. Although obtained from potato T′3 was severely pathogenic on tomato. The fungus had spread to potatoes growing in a home garden from an adjacent, blighted tomato field.

Isolates within the M′ category were divided into 2 groups according to their behavior. M′1 killed more tomato leaflets than P′ and less than T′ isolates. M′1 killed fewer potato leaflets than any other isolate. The other M′ isolates were typical of the potato race. Isolate M′4, although obtained from tomato fruit, was evidently of the potato race. The plot where the fruit was picked had been inoculated with P′1. P′ isolates were uniform in behaving like those of the potato race.

In general, the potato race failed to sporulate on tomato. Blighted tomato leaflets were placed in moist chambers for 48 hours. Only 2 of the 7 typical potato race isolates produced sporangia on the leaves. P′3 produced a single sporangiophore and M′3 produced an abundance of sporangia. The 4 typical tomato race isolates and M′1 produced sporangia in abundance. Thirteen days after inoculation, when the tomato plants infected with the tomato race were dead, tomato plants infected with the potato race still retained many healthy leaflets. The latter plants were placed in a moist chamber to induce sporulation. After 3 and 5 days there was no increase in number of leaflets killed and few sporangia were noted.

Detached leaf tests.—Four isolates were assayed for races by means of the sporangia produced on excised Rutgers tomato and Cobbler potato leaflets placed on moist filter paper in petri dishes. Four leaflets washed in tap water were inoculated with each isolate. A disk of medium 3 mm. in diameter was cut from the culture and placed mycelium side down in the center of each leaflet. Half the leaflets were placed at 59 and half at 68°F. Length of the area producing sporangia was measured parallel to the long axis of the leaflet after 5, 6, and 7 days. Four times 2^3 times 3 or 96 observations were available for analysis.

Manifestations of any pathic or hostic races are evident in the following table of lengths of sporulating areas. Each of the 8 figures in the body of the table is the mean of 12 observations.

Host	Isolate				Mean
	T′1	T′2	M′1	P′1	
T	27	32	23	6	22
P	16	18	25	10	17
Mean	22	25	24	8	20

On the average, smaller sporulating areas were produced on the potato leaves. P′1 produced significantly smaller areas than the other isolates and, hence, represented a pathic race in this experiment. M′1, which behaved in a unique manner in the greenhouse tests, behaved in an unusual manner here also. However, the important feature of these tests was that they verified the greenhouse tests. The interaction of host and pathogen was significant. Evidently hostic races exist and can be detected by the detached leaf method.

Because observations were taken at more than one temperature and more than one time, the existence of other types of races could be determined. The tomato race isolates produced significantly more disease than the other isolates at 68 but not at 59°F. Therefore, they behaved as environmental races under the conditions of this experiment. Time increase in the lengths was consistent for the 4 isolates. Therefore, there was no evidence of developmental races. The failure of time of observation to affect manifestation of virulent races in the detached leaf test, as it did in the test using entire plants, may be due to the test plants. On whole tomato plants the potato race kills the lower leaves and does not progress to the upper leaves. In the detached leaf test, all leaves are as nearly alike as possible. Therefore, the ability of the potato race to kill lower, but not upper tomato leaves, is not observed.

Field tests.—A field of interplanted potatoes and tomatoes was inoculated with isolate P′1. As reported (15), the fungus developed much more rapidly on potato than on tomato. This field test verified the greenhouse and excised leaf tests in which P′1, potato race, was found to develop slowly on tomato plants.

Attempted production of a tomato race.—An attempt was made to increase the pathogenicity upon excised tomato leaflets of 6 potato isolates of *Phytophthora infestans* from 2 potato growing regions. The isolates, 3 from Michigan and 3 from Minnesota, were serially transferred 7 times from excised Cobbler potato and Rutgers tomato leaflets. The leaflets were placed on moist filter paper in petri dishes and held at 59° F. Length and width of lesions produced on 4 excised leaflets for each host and isolate during the first and seventh transfer were determined. Measurements were made 7 days after a drop of sporangial suspension was placed at the center of each leaflet.

The means of the products of length and width for the 6 isolates are as follows:

Cultured on:	Tomato leaflets		Potato leaflets	
Inoculation:				
Host	1	7	1	7
T	12	14	19	28
P	10	15	14	22

Culturing the isolates from potato on excised tomato leaves did not increase pathogenicity upon tomato more than on potato. Culturing the isolates on potato leaves increased their pathogenicity about equally on both hosts and no hostic races were created. The observed increase in mean pathogenicity upon both hosts amounts to the production of pathic races. It was shown above that this is not a stable characteristic of the pathogen.

Failure to produce hostic races as done by Small (13) and Mills (9) can be ascribed to different methods because they used plants growing in the greenhouse. The observed stability of the hostic races on excised leaves explains the isolations of tomato and potato races from storage organs of the opposite host. Isolations of this type have been described by Mills (10) and in this paper.

SUMMARY

The study of variation in pathogenicity among isolates of *Phytophthora infestans* proceeds in 3 steps.

First, definitions are proposed, integrating past studies and permitting the use of quantitative experimental evidence. Four types of pathogen variants or races are defined in terms of amount of disease. First, if different isolates cause significantly different amounts of disease as shown by the average of the hosts, environments, and development times employed, they are called pathic races. Second, if different isolates cause significantly differential amounts of disease on different hosts, they are called hostic races. Third, if different isolates cause significantly differential amounts of disease under different environments, they are called environmental races. Fourth, if different isolates cause significantly differential rates of disease development, they are called developmental races. Significant interactions indicate that the expression of one of these races is affected by one or two of the other factors, e.g., environment and time.

Second, the existence of hostic races in isolates of *P. infestans* was demonstrated by greenhouse, detached leaf, and field tests. Manifestations of hostic races were found to depend upon environment and time of observation. The tomato race developed more rapidly and sporulated more copiously on tomato than did the potato race. The 2 hostic races were about equally pathogenic on potato. The 2 races were most often isolated from the host indicated by their name but could be isolated from the other host.

Third, hostic races were not created by culturing isolates from potato tubers on excised tomato and potato leaflets, demonstrating the stability of these races. It explained why isolates characteristic of the tomato race could be isolated from potato tubers and isolates characteristic of the potato race could be isolated from tomato fruit.

LITERATURE CITED

1. Crosier, W. 1934. Studies in the biology of Phytophthora infestans. Cornell Univ. Mem. **155**: 1-40.
2. De Bruyn, Helena. 1951. Pathogenic differentiation in Phytophthora infestans (Mont.) de Bary. Phytopathologische Zeit. **18**: 339-359.
3. Eide, C. J. 1935. Pathogenicity and genetics of Gibberella saubinettii. Minn. Agr. Exp. Sta. Tech. Bul. **106**: 1-67.
4. Giddings, N. J., and A. Berg. 1919. Comparison of the late blights of tomato and potato. Phytopathology **9**: 209-210.
5. Holton, C. S., and H. A. Rodenhiser. 1948. Physiologic specialization in the oat smut fungi and its relation to breeding oats for smut resistance. U. S. Department of Agr. Tech. Bul. 952.
6. Johnston, C. O. 1930. An aberrant physiologic form of Puccinia triticina Eriks. Phytopathology **20**: 609-620.
7. Martin, W. J. 1949. Strains of Phytophthora infestans capable of surviving high temperatures. (Abs.) Phytopathology **39**: 14.
8. Melhus, I. E. 1915. Germination and infection with the fungus of the late blight of potato (Phytophthora infestans.) Univ. of Wisc. Agr. Exp. Sta. Res. Bul. **37**: 1-64.
9. Mills, W. R. 1940. Phytophthora infestans on tomato. Phytopathology **30**: 830-839.
10. Mills, W. R. 1947. Tomato race of late blight overwintering on potato tubers in Pennsylvania. U. S. Dept. of Agr., Pl. Dis. Rptr. **31**: 230.
11. Müller, K. O. 1950. Affinity and reactivity of Angiosperms to Phytophthora infestans. Nature **166**: 392-395.
12. Reddick, D., and W. Crosier. 1933. Biological specialization in Phytophthora infestans. Amer. Pot. Jour. **10**: 129-134.
13. Small, T. 1938. Relation between potato blight and tomato blight. Ann. Appl. Biol. **25**: 271-276.
14. Snedecor, G. W. 1946. Statistical methods. Ames, Iowa. Iowa State College Press.
15. Wallin, J. R. 1951. Response of the tomato and potato in field plots inoculated with Phytophthora infestans. (Abs.) Phytopathology **41**: 37.

METHODS FOR REDUCING THE SPREAD OF THE WITCH'S BROOM DISEASE IN ALFALFA[1]

J. D. Menzies[2]

Alfalfa witch's broom is a leafhopper transmitted virus disease occurring in northwestern United States. In areas where it spreads rapidly, it has been an important factor in lowering yields and thinning out stands. Plowing out of diseased fields and reseeding has often been unsatisfactory because of disease spread into new plantings. Accumulated knowledge on the characteristics of the disease indicates that this continuing invasion of new seedings can be prevented by destroying diseased fields on an area basis and by encouraging dense, vigorous new stands.

CHARACTERISTICS OF INFESTED AREAS. — Alfalfa witch's broom occurs in scattered areas throughout the inter-mountain region of western United States and Canada, and east of the Rocky Mountains in Alberta. The host range and geographic distribution of this disease have been detailed in previous publications[3,4]. A common feature of seriously infested localities is that they are relatively small, isolated alfalfa producing areas typified by small fields adjacent to non-agricultural land. This is the case in the Methow Valley of Washington, the Nicola and Kamloops areas in British Columbia, the Snake River bench land in Elmore County, Idaho, and the Umatilla area of Oregon.

The Yakima Valley of Washington, in contrast, is an extensive alfalfa producing area. Although witch's broom has been present there for at least 20 years, it is a minor disease. Found occasionally in old stands and in orchards, it is a troublesome disease at the Irrigation Experiment Station, Prosser, in small experimental fields, old plots, or row plantings

A typical example of how this disease spreads in row plantings as compared with solid seedlings is offered by 2 adjacent plots at the Irrigation Experiment Station. One plot was a broadcast planting of the Ladak variety, the other a nursery of various selections planted in rows 2 ft. apart. Both were approximately ½ acre fields and were planted at the same time. Incidence of witch's broom was recorded each year in these plots during a 5-year period. The field planted in rows contained 0.4, 4.5, and 30.8 per cent witch's broom after 3, 4 and 5 years respectively. The broadcast-planted field contained only 0.25 per cent infected plants after the 5 years. The difference is striking even if expressed on a unit area basis, making allowance for the difference in plant population. Unpublished varietal susceptibility data show that Ladak is not more resistant than the other selections.

Only 2 of the larger alfalfa fields on the experiment station farm have more than a trace of infection at the present time. One is a 10-year-old field of Turkestan planted in rows for seed production. Witch's broom infection in this field is over 50 per cent. The other is a 9-year-old, very thin stand of Ladak adjacent to witch's-broom infected variety plots. The disease has spread slowly through this field from the infected plots but has not damaged other nearby fields.

THE BORDER EFFECT OF DISEASE SPREAD.—A distinct tendency for witch's broom to spread slowly into a field from the margins has been observed, particularly in heavy stands when the disease first appears. It is most evident where a badly diseased field serves as a nearby source of infection. Disease counts have been obtained from a number of fields to illustrate this effect. In obtaining the data, the number of infected plants per 1,000 sq. ft. was calculated for 6-ft. concentric bands laid off from the margins of the field. Results are in Table 1. The border effect can be seen in the 5-year-old thick stand and in the young row plantings. But it has disappeared in old plantings where the stand is poor and disease readings high.

THE EFFECT OF ISOLATION.—Indirect evidence for the value of isolation in protecting new plantings can be taken from the data in Table 1. Slow spread from diseased fields into new seedings has been repeatedly observed. The disease does not usually occur at random unless the fields are small and the disease incidence in the area is unusually high.

The effectiveness of isolation can be further illustrated by the results of a test planting in the Methow Valley. Plots containing a number of alfalfa varieties and other forage legumes were planted in 1941 on a cooperator's farm. This farm was almost entirely in alfalfa of various ages, with witch's broom infection ranging from 10 to 70 per cent. In 1942, the disease was prevalent in the plots and increased rapidly in 1943. That year, however, decreased hay production forced the cooperator to plow out his entire alfalfa acreage, leaving the test plots isolated from other diseased alfalfa by ½ mile. In the following 2 years there were no new infections recorded, while the percentage disease decreased through the death of diseased plants. The experiment failed to provide a test of varietal susceptibility, but it demonstrated control of disease spread by isolation.

The only known vector of this disease in the United States is the leafhopper *Scaphytopius dubius* (Van Duzee) (1, 2). The observed incidence and spread of witch's broom indicates that the vector lives and breeds more freely in other vegetation than in alfalfa and

[1]Accepted for publication August 13, 1952.

[2]Pathologist, Division of Soil Management and Irrigation Agriculture, Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture, Prosser, Washington.

[3] Klostermeyer, E. C. and J. D. Menzies. 1951. Insect Transmission of alfalfa witch's broom virus to other legumes. Phytopathology 41: 456-458.

[4] Menzies, J. D. 1946. Witches' broom of alfalfa in North America. Phytopathology 36: 762-774.

TABLE 1.—*Distribution of alfalfa witch's broom within alfalfa fields of different ages and stand densities*

Field Description	Number of infected plants per 1,000 sq. ft. at the following distance from edge of field							
	0-6′	6′-12′	12′-18′	18′-24′	24′-30′	30′-36′	36′-42′	42′-48′
Thick stand, 5 yrs. old	136	93	64	45	35	28	25	
Row planted, 3 yrs. old	10	11	14	9	8	4		
Row planted, 3 yrs. old	75	86	76	45	33	18	19	3
Row planted, 5 yrs. old	263	319	251	331	285	277	308	
Thin stand, 6 yrs. old	83	36	55	83	75	123	91	103

does not move freely or rapidly in alfalfa fields. The fact that thin stands or row plantings are more rapidly attacked by the disease may mean that the vector does not tolerate the dense shade and high humidity found in heavy stands of alfalfa.

CONTROL BY COMMUNITY ACTION.—The above observations led to a recommendation that old witch's broom infected alfalfa be plowed out over as large an area as possible to reduce the source of disease for new plantings. Measures to insure more productive stands such as better varieties, better seedbed preparation, proper fertilization and more careful irrigation were also urged. Because of the general deterioration of alfalfa hay yields in the Methow Valley, these practices were strongly recommended by the Soil Conservation and County Extension Services. Since 1946, the growers there have followed these practices to the extent that almost all of the very old alfalfa fields have been replaced by new seedings of better adapted varieties. Improved management practices are evidenced by thick stands and more uniform growth.

Results in control of witch's broom have been striking. In 1951, no more than a trace of witch's broom could be found in any of the fields where prior to 1946 infections of 50 to 70 per cent were common, even in young plantings 3 or 4 years of age.[4] While it is not certain that the virtual disappearance of the disease since 1946 has been due to these control measures, it seems unlikely that natural causes unrelated to these management practices could have been largely responsible. Since these control recommendations are merely those that can be encouraged for good alfalfa production under normal circumstances, they should be worth testing in other areas where witches' broom is a problem.

DISCUSSION.—If this elimination of witch's broom has been due to the destruction of most of the virus sources in alfalfa it follows that there is not an important carry-over of virus from year to year in the native vegetation or in the over-wintering stages of the leafhopper vector as is the case, for example, with the curly top virus. Data also indicate that the vector or vectors are not widely migratory like the beet leafhopper, the vector of curly top. Otherwise the observed border effects would be less evident and the value of isolation would be more doubtful.

A similar decrease in witch's broom in Utah in the early 1930's was attributed to the beneficial effects of short rotations forced on the growers by the appearance of bacterial wilt.[5] Use of wilt-resistant varieties may lead to longer-lived stands, and witch's broom may again become a factor in that area.

Witch's broom also occurs in pastures and attacks ladino clover and white Dutch clover as well as alfalfa (1, 2). If the slowness of spread in dense hay fields is due to the effect of shade on the activities of the vector, pastures may present a more difficult problem. More frequent renewal of pastures may be necessary both to keep up pasture production and to protect hay fields.

SUMMARY

Alfalfa witch's broom is especially serious in areas where small fields and permanent plantings have been the custom. The disease spreads more rapidly in small, thin stands than in larger, dense plantings. Its range of spread is not great and benefits from isolating new plantings are reported. Experience in the Methow Valley of Washington indicates that area-wide removal of old, diseased fields followed by reseeding and the maintenance, through good cultural practices, of dense, productive stands is an effective means of preventing spread into new plantings.

IRRIGATION EXPERIMENT STATION
PROSSER, WASHINGTON

[5] Personal correspondence from B. L. Richards.

PARATYLENCHUS HAMATUS PATHOGENIC TO CELERY[1]

B. F. Lownsbery[2], E. M. Stoddard[2], and J. W. Lownsbery[3]

Paratylenchus hamatus Thorne & Allen 1950 (Nematoda: Criconematidae) was described from California[4] where it is associated with leaf drop and decline of the fig tree. During the growing season of 1951 populations of *P. hamatus* as high as 10,000 per pound of soil were found in fields of stunted and chlorotic celery plants in Connecticut, Massachusetts, and New Hampshire.[5] Stunted plants take longer to reach salable size, and severely affected plants are never salable. *P. hamatus* larvae and egg-bearing females have been observed feeding externally on all parts of celery roots (Fig. 1) and dill roots from these fields. The relation of *P. hamatus* population levels to disease severity was studied as a clue to the pathogenicity of the nematode. Because *Fusarium* and *Rhizoctonia* can sometimes be isolated from lesions on the stunted roots interrelations between *Fusarium* and *P. hamatus* in the disease were investigated.

P. HAMATUS POPULATION LEVELS AND DISEASE SEVERITY.—*Materials and methods.*—Soil heavily infested with *P. hamatus* was screened and coned for uniformity, then divided into 2 lots, one of which was treated with methyl bromide. The untreated soil contained approximately 36000 *P. hamatus* per 6 in. pot. There were no other plant parasitic nematodes present. The methyl bromide treated soil contained practically no viable nematodes. Intermediate populations of approximately 18000 and 3600 *P. hamatus* per pot were obtained by dilution of untreated soil with methyl bromide treated soil. Cornell #19 celery plants were transplanted to these soils. Fresh weights of celery plants were taken, and nematode populations were checked by screening after celery plants had grown 10 weeks.

TABLE 1.—*Celery yield at 4 levels of P. hamatus infestation*

No. *P. hamatus* per plant	Celery fresh wt. in gms.	
	Older[a] plants	Younger[b] plants
0	161	143
3600	138	112
18000	129	53
36000	77	38
L.S.D. at 5% level	21	14
L.S.D. at 1% level	28	19

[a] Plants 15 weeks old at time of infestation; mean of 9 replicates.

[b] Plants 10 weeks old at time of infestation; mean of 7 replicates.

Results.—Celery weight was inversely proportional to the initial *P. hamatus* population (Table 1). Yield reduction was significant even with the lowest *P. hamatus* population (3600 per plant). *P. hamatus* populations increased at the 3600 level and decreased at

FIG. 1.—*P. hamatus* female killed with boiling lactophenol while feeding in the piliferous region of a celery root.

[1]Accepted for publication August 13, 1952.

[2]The Connecticut Agricultural Experiment Station, New Haven.

[3]Dept. of Zoology, Yale University, New Haven.

[4]Thorne, G., and M. W. Allen. 1950. Paratylenchus hamatus n. sp. and Xiphinema index n. sp., two nematodes associated with fig roots, with a note on Paratylenchus anceps Cobb. Proc. Helm. Soc. Wash. 17[1]: 27-35.

[5]Identification was made on a morphologic basis and will have to be revised if host preferences of the California and New England nematodes prove different.

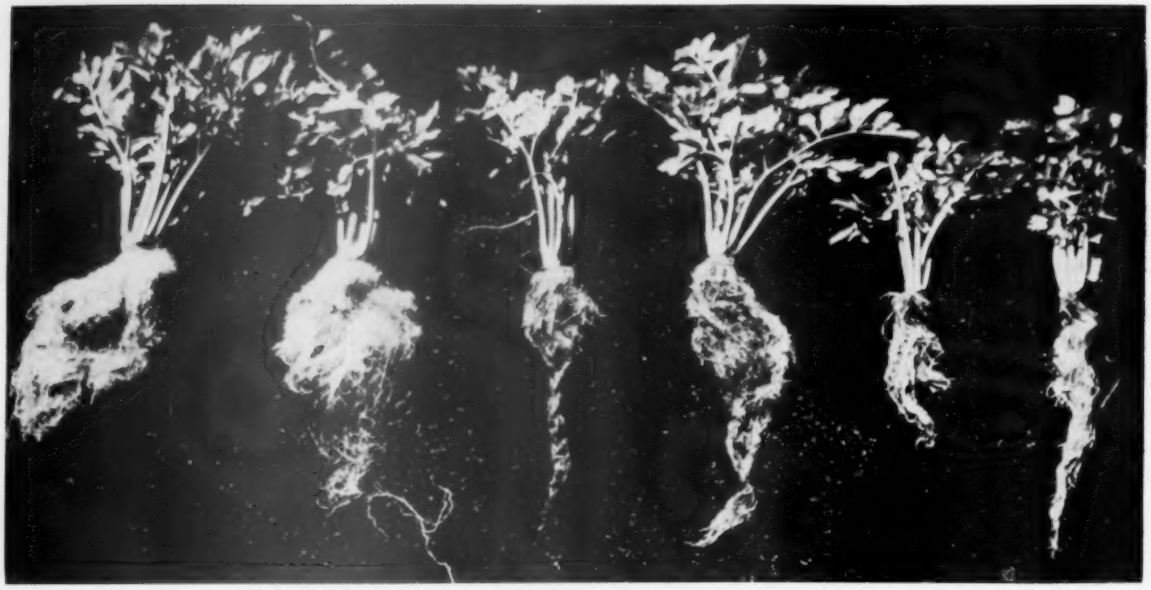


FIG. 2.—Celery plants produced in soils containing 0, 18000, and 36000 *P. hamatus* per pot.

the 18000 and 36000 levels. Suitable feeding sites were apparently limiting on the smaller plants (Fig. 2) produced at the higher levels of *P. hamatus*.

EFFECT OF P. HAMATUS AND FUSARIUM SP. INFESTATION.—*Materials and Methods.*—Pascal celery plants were grown from seed in nematode free sand. When 10 weeks old they were transplanted to small (4 × 4 × 3 in.) wooden boxes containing a nematode-free (methyl bromide treated) fine sandy loam fertilized to correct deficiencies, and coned for uniformity. A nematode suspension was obtained from soil heavily infested with *P. hamatus* by a modification of the Cobb[6] screening-gravity method. *P. hamatus* was the only plant parasitic nematode present in the suspension which also contained *Rhabditis*, *Dorylaimus*, and *Cephalobus* species. A *Fusarium* inoculum was isolated from lesions in *P. hamatus* infested celery from the field and obtained in pure culture in quantity on bran. The celery plants were divided into 4 lots of 12 each. Three of these 4 lots received volumes of stirred nematode suspension such that they were infested with 500, 2500, and 12,500 *P. hamatus* per plant. The fourth lot was an uninfested control. Half the plants in each of the 4 lots were then infested with the *Fusarium* from celery roots. The fungus, together with approximately 5 gms. of the bran substrate, was mixed into the top inch of soil. Plants were watered regularly and the greenhouse maintained at 70° F. After 3 months fresh weights of celery plants were taken and nematodes in each replicate were screened from the soil and counted.

Results.—Stunting was significant at the highest *P. hamatus* level (Table 2). Chlorosis at this level was quantitatively significant as shown by higher reflected light readings on a photographic exposure meter.

[6]Cobb, N. A. 1918. Estimating the nema population of soil. U.S.D.A. Agric. Technology. Circ. 1.

Fusarium alone produced no stunting and *Fusarium* did not increase nematode stunting under the conditions of this experiment. Plants which had been infested with *Fusarium* were more vigorous than plants which had not received the fungus (Table 2). It was thought that this might have been an effect of the 5 gm. of bran substrate added with the fungus. Soil analyses at the end of the experiment showed no higher nutrient level in replicates containing bran. They did show that nutrients were low in all boxes by the end of the experiment. It is possible that the bran may have given a boost at some time during the course of the experiment.

The *P. hamatus* population increased at the 2 lowest levels of initial addition and decreased at the highest level of addition (Table 3). It is believed that the smaller plants produced at the highest *P. hamatus* level could not support as many nematodes as could the larger plants produced with the lower *P. hamatus* population. Addition of *Fusarium* and bran had no effect on *P. hamatus* population, but supported a sig-

TABLE 2.—*Celery yield at 4 levels of P. hamatus infestation with and without Fusarium sp.*

No. *P. hamatus* per plant	Plant wt. in gms.[a]	
	Without Fusarium	With Fusarium[b]
0	35	43
500	30	37
2500	31	32
12500	24	26
L.S.D. at 5% level	7	
L.S.D. at 1% level	9	

[a] Mean of 6 replicates.
[b] Added with approximately 5 gms. bran substrate per box.

nificantly larger number of saprophytic nematodes (Table 3).

TABLE 3.—*Nematodes recovered from celery plants grown 3 months at 4 levels of P. hamatus with and without Fusarium*

No. *P. hamatus* added initially	Final aliquot[a] recovery of nematodes[b] Without *Fusarium* and bran		With *Fusarium* and bran	
	P. hamatus[c]	saprophytic[d]	*P. hamatus*[c]	saprophytic[d]
0	1	51	1	165
500	10	41	13	235
2500	19	31	12	123
12500	15	52	17	114
L.S.D. at 5% level	[c]10		[d]72	
L.S.D. at 1% level	[c]13		[d]96	

[a] Number of nematodes in aliquot = approx. 1/400 total number of nematodes in box.
[b] Mean of 6 replicates.

DISCUSSION.—The close association of *Paratylenchus hamatus* with this disease, the ease with which it can be produced by infesting with *P. hamatus*, and the correlation of disease severity with number of *P. hamatus* indicate that this nematode is the primary pathogen. It cannot be concluded from the single experiment with *Fusarium* that soil fungi do not contribute as secondary invaders.

Because of the external feeding habit, sluggish movement, and small size of *P. hamatus*, it can best be found by screening suspected soils. Since populations have been found at pathogenic levels throughout the year, it is concluded that the nematode can survive New England winters.

SUMMARY

In greenhouse experiments *Paratylenchus hamatus* has produced the same stunting and chlorosis of celery commonly associated with the nematode in the field. Disease severity is proportional to the *P. hamatus* population. Larvae and adult females containing eggs have been observed feeding on diseased celery and dill roots. A *fusarium* sp. isolated from *P. hamatus* infested celery roots did not stunt celery or increase nematode stunting in a single trial.

PURPLE LEAFSPOT OF ORCHARD GRASS [1]

J. H. Graham [2]

Purple leafspot, caused by *Stagonospora maculata* (G.) Sprague, is a major disease of orchard grass (*Dactylis glomerata* L.) in the Northeast. Leaf lesions can be found on almost all plants of the grass throughout the growing season. Often entire blades are killed and the culms and heads attacked, apparently reducing the productivity of the crop. Although the disease is widespread, only leaf symptoms and a description of the causal organism have been reported. This paper gives results of studies on host range, life history, physiology and epidemiology of the causal fungus.

THE DISEASE.—*Symptoms.*—The symptoms of purple leafspot have been reported as subelongated, blackish-brown blotches[3] and blackish-brown to purple lesions containing pycnidia in lines[4] on leaves of orchard grass. In the present investigation symptoms were observed throughout the growing season. The disease first appears as tiny (1 mm. diameter) watery spots which later become purplish-black. Centers of older lesions occasionally become lighter colored. The lesions, partially restricted by veins, increase primarily in length (2–5 mm.); however, if several coalesce, portions of, or the entire, blade may be killed. Subepidermal pycnidia, frequently not readily visible without magnification, develop in the necrotic tissue.

Symptoms of *S. maculata* often vary on different clones of orchard grass. Lesions may not develop the purple-black color but become light to reddish-brown, occasionally with slight chlorosis. Small red "eye" spots with brown to purple margins and lighter centers also occur. The first lesions in spring are usually some shade of brown, often with ashen centers. In the latter case black pycnidia may be visible under the raised epidermis. Purplish-black lesions also develop on the sheaths, culms, and heads of mature plants, frequently killing entire blades and sheaths. Black, sub-epidermal pycnidia are often detectable on the thin glumes.

Young watery lesions may be mistaken for symptoms of several other diseases of orchard grass, principally, leaf streak caused by *Scolecotrichum graminis* Fckl. and anthracnose caused by *Colletotrichum graminicola* (Ces.) Wils. However, as the lesions increase in size the symptoms are easily distinguished since those of the former greatly elongate and those of the latter become oval with many setose acervuli in the bleached necrotic areas. *S. arenaria* Sacc. causes a purple to brown blotch of orchard grass which also might be mistaken for *S. maculata*. However, accord-

[1] Accepted for publication September 13, 1952.

Contribution No. 113 of the U. S. Regional Pasture Research Laboratory, Division of Forage Crops and Diseases, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, State College, Pennsylvania, in cooperation with the twelve Northeastern States.

[2] Agent (Plant Pathologist).

[3] Grove, W. B. 1935. British stem- and leaf-fungi (Coelomycetes). Vol. I. Sphaeropsidales, Cambridge, England: 488 pp., illus.

[4] Sprague, R. 1950. Diseases of cereals and grasses in North America. The Ronald Press Company, New York: 538 pp., illus.

ing to Sprague[4,5] the blotches become buff in the center, develop a few scattered pycnidia and finally fade to straw color whereas the lesions of the latter fungus normally remain dark and develop linear pycnidia.

Host range.—*S. maculata* has been reported only on *Dactylis glomerata*.[6] The susceptibility of 12 species of grasses in 10 genera was determined in greenhouse inoculations. The following species were tested as seedlings: *Avena sativa* L., *Bromus inermis* Leyss., *Dactylis glomerata* L., *D. aschersoniana* Graebn., *Elymus canadensis* L., *Pestuca arundinacea* Schreb., *Festucaelatior* L., *Phalaris arundinacea* L., *Phleum pratense* L., *Sorghum sudanense* (Piper) Stapf. and *Triticum aestivum L.* Many of these species also were tested as mature plants. In 3 experiments only the 2 species of *Dactylis* were susceptible.

THE CAUSAL ORGANISM.—While studying *S. subseriata* (Desm.) Sacc., Grove[3] found a distinct form on *D. glomerata*. Although the spores were somewhat similar this form was more pathogenic and formed pycnidia in lines on the subelongated lesions. Sprague[4] examined specimens from Pennsylvania and Maryland which he believed to be identical with Grove's collection. He gave them species rank due to the distinct differences in morphology as well as pathogenicity. Although *S. arenaria* produces somewhat similar symptoms on orchard grass, Sprague considers the morphology of the spores to be quite distinct from those of *S. maculata*. The latter differ in being thick and constricted with yellow, coarse contents.

The morphology of the fungus studied agrees more closely with that of *S. maculata* than that of *S. arenaria*, although generally spores are slightly longer and narrower. Another important variable was the amount of constriction at the septa. Spores from 3 fall collections which had been stored in a refrigerator for several months showed practically no constrictions. Few of the spores produced in culture were constricted. However, conidia from overwintered tissue and from new spring leaves were usually constricted and contained large globules near the septa. In some instances the indentations were slight and often only at the median septum. In one collection of overwintered stems, spores had exuded from some of the pycnidia and dried. Several hundred of these spores were examined and all found to be constricted. Spores from the collections were mostly 3 septate as reported by Sprague, but those in culture had from 3 to 7 septa with a mode of 4. Another agreement with the spores of *S. maculata* was the blunted base and sharper apex.

Size of the pycnidia varied considerably, probably due, in part, to stage of maturity. Pycnidia from stored dried leaves were smaller; those formed in culture were larger than those of the type species.

Sporulation and growth in culture.—As with most species of *Stagonospora* on grasses, *S. maculata* failed to sporulate on common laboratory media. In an attempt to produce spores, 4 isolates were grown on 7 media at room temperature. One isolate remained sterile on all media. The others failed to sporulate on potato-dextrose agar and produced only occasional pycnidia on cornmeal, bean pod, and alfalfa infusion agar. Good sporulation occurred on soybean agar (Venue tablets), clover infusion agar, and sterile birdsfoot trefoil stems.

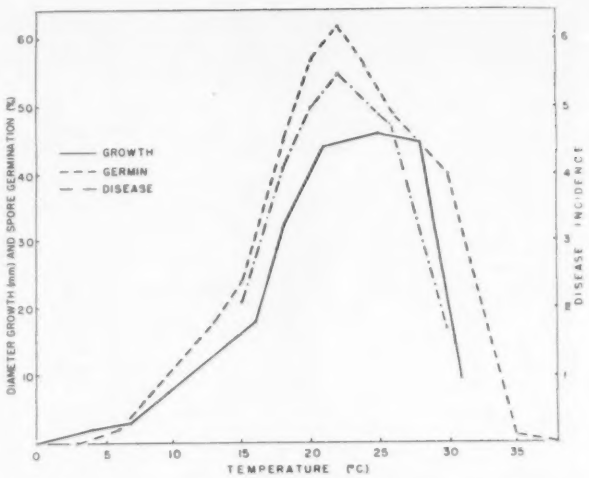


FIG. 1. Relation of temperature to mycelial growth, spore germination and disease incidence of *Stagonospora maculata*.

The effect of temperature on colony growth and sporulation was determined, using a range of 4° to 31° C. Following standard procedures 3 isolates were grown on soybean agar; colony diameter and pycnidia production were recorded after 10 and 21 days, respectively.

Since growth rates of the 3 isolates varied only slightly, they are combined in Fig. 1. Good growth was obtained between 22° and 28° C. with an optimum at 25° C. for 2 isolates and 22° C. for the other. Two cultures produced pycnidia at 19°–25° C. while the third remained sterile at all temperatures. Pycnidia containing micro-conidia developed in some cultures.

Cultural characteristics varied little among isolates and at different temperatures. The colonies were characterized by raised, dense, cottony, white mycelium with even margins. Older colonies often became grayish-white and some cultures developed a pinkish cast at the centers. At higher temperatures the marginal mycelium was somewhat submerged. On potato-dextrose agar, the mycelium formed a dense, white, cottony mat with entire margins.

Spore germination.—Further data on effects of temperature on the fungus were obtained by germinating spores in sterile, distilled water on glass slides at intervals from 3° to 38° C. To prevent spreading of the water two rings were made on each slide with a china-marking pencil. Individual slides were placed in Petri dish moisture chambers and held for 3 hours.

[5] Sprague, R. 1941. Stagonospora arenaria on grasses. Mycologia 33: 371-379.

[6] K. W. Kreitlow, formerly at the Pasture Laboratory, obtained positive infection on Dactylis aschersoniana in the greenhouse.

Results of 3 tests indicate that the optimum temperature for germination is 22° C. (Fig. 1). Germ tubes were also longer near this temperature. After 12 hours a low percentage of spores had germinated at 3° C., but none germinated at 38° C. The mode of germination was noted in these tests. Three-septate spores normally produced a lateral germ tube from each end cell or 2 laterals from 1 end and 1 from the other. Spores with more than 3 septa usually formed germ tubes from 1 of the intermediate cells as well as the end cells.

EPIDEMIOLOGY.—Since almost all orchard grass plants in the Northeast are attacked by the purple spot fungus and because a marked increase in disease incidence has been observed even during dry seasons, it seemed important to investigate the epidemiology of the causal organism. First, tests were conducted to determine the effects of various temperature and moisture conditions upon infection and disease development. In 4 experiments, tillers from a susceptible orchard grass clone were inoculated with spore suspensions made from diseased leaves of this same plant. Plants in the first 3 tests were kept in a 3-sectional meat case in the greenhouse at the following temperatures: Test 1—15°, 20°, 25° C.; Test 2—22°, 26°, 30° C.; and Test 3—20°, 22°, 25° C. Transparent "polyethylene" bags were placed over the plants after inoculation to retain the moisture. The fourth inoculation test was conducted in 4 temperature control chambers at 18°, 22°, 26° and 30° C. at 100 per cent relative humidity and under approximately 500 foot-candles for 16 hours each day.[7] Fifteen to 20 clones were inoculated and held at each temperature in the 4 tests. In each experiment, except No. 3, plants were kept moist for 6, 12, 24, 48, and 72 hours, then dried with an electric fan and held at approximately 20-25° C. until 9 days after inoculation when disease readings were taken. Plants in test 3 were kept in the meat case at approximately 100 per cent relative humidity for 72 hours and 40–60 per cent for the remainder of the experiment.

To determine the effect of temperature on disease incidence, ratings of plants which were kept moistened 48-72 hours after inoculation in the 4 tests were combined and plotted in Fig. 1. Severe infection occurred from 20° to 26° C. with most damage (55 per cent of leaf area killed) at 22° C. Plants were moderately diseased even at 15° and 30° C.

Influence of different periods of high humidity after inoculation was determined from the 3 experiments previously described. Plants which were kept moistened for 6 hours at 20° to 26° C. and then dried developed a few lesions after 3 days. By keeping the plants wet another 6 hours the number of lesions increased almost 20-fold while only slight infection occurred at the lower and higher temperatures. When plants were kept at a relative humidity of 100 per cent for 24 hours and readings taken 7 days later, those incubated at 15°, 18° and 20° C. developed 20 times as many lesions as those kept moist for 12 hours, whereas at other temperatures, the number of lesions increased only 4 to 8 times. Plants retained in a saturated atmosphere another 24 hours (total of 48 hours) and then dried, developed twice as many lesions except at 22° C. where the increase was smaller. There was only a slight increase in infection from 18° to 25° C. when the plants were kept 72 hours instead of 48 hours at high humidity. A comparison of the disease incidence under the various periods of 100 per cent relative humidity at 22°–25° C. is presented at the bottom of Table 1.

TABLE 1.—*Progress of germination, penetration and infection by Stagonospora maculata at 22°-25° C. after various periods of 100 per cent relative humidity after inoculation*

	Hours			
	6 %	12 %	24 %	48 %
Not germinated	35	25	13	12
Short germ tubes	54	59	20	15
In process of penetrating	11	16	67	73
Disease incidence [a]	1	12	66	85

[a] On basis of inoculated plants held at 100 per cent relative humidity until maximum infection occurred (84-96 hours).

Host penetration.—No record has been found in the literature concerning the penetration of hosts by graminicolous species of *Stagonospora.* In 2 of the preceding experiments, pieces of inoculated leaves were collected 6, 12, 24 and 48 hours after inoculation, cleared in acetic acid and alcohol, and stained with cotton blue in lactophenol. Counts were made of spores which had not germinated, spores with short germ tubes, and those which had penetrated or were in the process thereof (Table 1). Approximately 100 spores were examined from each collection.

Within 6 hours 65 per cent of the spores on the leaf surface had germinated and 11 per cent had produced appressoria. The percentage of germination increased up to 24 hours while the number of germ tubes which had penetrated or were in the process of penetration had increased at each successive time of examination. Within 48 hours the mycelium had ramified in the tissues and emerged from stomates on the opposite side of the leaf. The penetrated area did not completely clear in the acetic acid-alcohol solution but became light brown in color. Disease incidence, determined after rapidly drying the plants 6, 12, 24, and 48 hours after inoculation, increased proportionately with the percentage of penetration.

Penetration occurs generally by the formation of appressoria at the point where epidermal cells adjoin. In several instances infection hyphae entered between a guard cell and an adjacent epidermal cell. When stomatal penetration occurred an appressorium usually formed over the opening.

[7] The assistance of Dr. V. G. Sprague of the U. S. Pasture Laboratory in the operation of the control chambers is acknowledged.

Overwintering.—Observations were made on the means of overwintering of *S. maculata.* Leaves and culms of orchard grass were collected throughout the year and examined for fruiting bodies. Pycnidia with viable spores were found during winter and spring; however, some immature pycnidia were observed in early spring in dead leaves, indicating that the fungus may also persist as mycelium. By the last of March in the Pennsylvania State College area, lesions devoid of the purple color had developed on the new spring leaves. In several collections mature pycnidia were observed in lesions on new growth which apparently had been killed by cold. Stem pieces of the previous season collected in early April contained pycnidia from which spores had exuded and dried. By this time typical purple lesions were evident on the green leaves. To determine whether or not the fungus is seedborne, isolations were made from 3 lots of orchard grass seed. Although the outer glumes were infected, the fungus was not recovered from cleaned seed. In the greenhouse, artificially inoculated seed did not show reduced germination nor did the young seedlings become diseased.

Although 2 ascomycetes (*Leptosphaeria* sp. and *Pleospora* sp.) were found near pycnidia of *S. maculata*, neither proved to be the sexual stage of the pathogen.

Control.—At present the most practical means of controlling purple leaf spot of orchard grass appears to be through host resistance. With this in mind many selections in the field plantings were rated for disease incidence. Seed of selections showing least disease was planted in flats of soil in the greenhouse. After 3 inoculations some of the seedlings developed only brown atypical lesions while a few were apparently free of disease. These will be studied further for possible use in a breeding program.

Discussion.—The first problem of this study was to determine whether or not *S. maculata*, *S. arenaria*, or both were causing the purple lesions on orchard grass, since the spore morphology of the material under study had characteristics of both. *S. arenaria* is being used as a catch-all for forms with spores slightly thicker than those of *Septoria* sp. while the spore morphology of *S. maculata*, described from only 2 collections, has rather narrow limits. One of the major variables was the degree of constriction in the spores. The material examined in this study varied from none (as *S. arenaria*) to strongly constricted (as *S. maculata*). Observations indicate that the age of the spore may influence this characteristic since pycnospores from young tissue usually ranged from those deeply to those slightly or not at all constricted, while exuded spores, which may be considered mature, were all constricted. All spore types were used in greenhouse inoculations. Resulting symptoms and host range agreed with those given for *S. maculata.*

The present study indicates that the fungus is much more variable than previously described. It is suggested that the morphological limits be extended to include the types discussed in this paper.

The prevalence of purple leafspot can be partially explained by the adaptability of the fungus to a wide range of temperature and the rapidity of penetration and infection. In a saturated atmosphere at temperatures near the optimum, penetration and some infection occurred within a few hours. It is known that these temperatures and humidity conditions occur in the plant zone during many summer nights even in the absence of rain. Thus, as observations indicate, disease incidence may increase even during periods of low rainfall.

SUMMARY

Purple leafspot caused by *Stagonospora maculata* is a major disease of the above-ground parts of orchard grass in the Northeast. The disease first appears as tiny watery spots which develop into subelongated, purplish-black lesions, 2-4 mm. long. In greenhouse inoculations of 12 species representing 10 genera of forage grasses only *Dactylis glomerata* and *D. aschersoniana* were susceptible. Most isolates produced pycnidia on soybean agar and sterile birdsfoot trefoil stems. Optimum temperature for mycelial growth was near 25° C. while best spore germination and infection were evident at 22° C. With favorable temperature and moisture conditions, penetration and some infection occurred within 6 hours. Penetration was direct (usually between epidermal cells), and through stomates. Studies show that the fungus overwinters as pycnidia and mycelium in leaves and stems of orchard grass. Preliminary data indicate that high resistance may be obtained by selection.

U. S. Regional Pasture
Research Laboratory
State College, Pa.

THE VITAMIN NUTRITION OF ALTERNARIA SOLANI[1]

Ralph W. Lewis

The nutrition hypothesis of parasitism states that a parasite grows in a particular host, or organ, because there is available to the parasite in that host, or organ, the kinds and quantities of foods necessary for its life, and in resistant hosts, or organs, the necessary kinds and/or quantities are absent or unavailable to the parasite (1,3,5). Probably no one doubts the first half of this hypothesis, yet it is a statement without verification in detail and as such must remain suspect from the operational point of view. The total nutrition of a parasite living in its host has not, in a single case, been closely approximated with certainty in either plants or animals. In other words, there is no analytical proof for what is accepted as self-evident fact. The second half of the hypothesis may be less readily acceptable because of known factors of resistance which operate in some cases. Despite this it remains a reasonable possibility which must be investigated as a part of the total problem of the host-parasite relationship.

It is probable that the most economical means of investigating the nutrition hypothesis is to study the nutrition of the parasite *in vitro* and then, with this knowledge as a guide, to begin analysis of resistant and susceptible hosts. The present paper contributes information about the effects of 13 vitamins, and a few other substances, on the growth of a common pathogen.

MATERIALS AND METHODS.—The isolate of *Alternaria solani* used in these studies was secured from a tomato fruit with typical symptoms in the summer of 1948 and has been grown on potato dextrose agar by transferring every 2 to 4 weeks. The methods followed in testing the growth of this organism were essentially those used in the author's *Neurospora* research (7) and described in detail by Beadle and Tatum (2). The *Alternaria* cultures were, however, shaken constantly during growth on a machine with a 1-in. stroke and with 100 strokes per minute. Cultures were grown in 125 ml. flasks with 20 ml. of medium. A temperature of 27° C. ± 1° was used for all experiments.

The basal medium consisted of ammonium nitrate 2.0 gm., potassium dihydrogen phosphate 2.0 gm., magnesium sulfate $7H_2O$ 0.5 gm., sodium chloride 0.1 gm., anhydrous calcium chloride 0.1 gm., minor elements solution (2) 1 ml., cp glucose 20.0 gm., and distilled water 1000 ml. The following vitamins were tested and used in the concentrations noted here as mg. per liter unless otherwise stated: thiamine hydrochloride 1.0, riboflavin 0.5, pyridoxine hydrochloride 0.5, calcium pantothenate 2.0, p-aminobenzoic acid (PAB) 0.5, nicotinamide 2.0, i-inositol 4.0, pimelic acid 4.0, choline chloride 2.0, nucleic acid 5.0, folic acid 0.004, d-biotin 0.005, and B_{12} 0.05. The pH of the medium as prepared was between 4.0 and 4.5 and did not change outside of this range upon autoclaving. Since this pH was found to be within the optimum range for the growth of the fungus, no adjustments were made. All media except those containing B_{12} or folic acid were autoclaved, after mixing, for 10 minutes at 15 lb. pressure. B_{12} and folic acid were sterilized in fritted glass filters and added after the remainder of the medium was autoclaved. All chemicals used were of the highest purity commercially available and were free from assayable levels of biotin, choline, and thiamine.

The inoculum consisted of 1 drop of mycelial suspension per flask. The suspension was prepared by removing the mycelial growth from a 2- to 3-weeks old potato dextrose agar slant culture and blending it for 2 minutes in 25 ml. of sterile water. The amount of growth was determined by straining the culture through nylon cloth, pressing the water from the mycelium, drying overnight at 80° to 100°C., and weighing.

All flasks were run in duplicate. Early in the work much variation occurred between duplicate flasks. More careful attention to glassware before it was treated with dichromate cleaning solution plus the use of a rinsing apparatus relieved some of the difficulty. Further variation was removed by the use of Pyrex glass wool plugs. In the experiments reported here the figure given for growth is the average of 2 flasks. Since most experiments were repeated 2 to 4 times, the experiment which contained the occasional discrepancy between duplicate flasks was not reported.

GROWTH FACTORS.—Preliminary experiments gave good growth in 3 to 4 days on basal medium plus yeast extract. When a mixture of the vitamins noted above, except for B_{12}, was substituted for yeast extract, almost equally good growth resulted. A series of experiments using different mixtures of 4 of the vitamins followed by experiments with individual vitamins, demonstrated that no appreciable growth was secured with a single vitamin, but fair growth (30 mg. mycelium) was produced if both biotin and choline were present, and good growth (59 mg.) resulted if biotin, choline, and thiamine were added.

These results made reasonable the assumption that *Alternaria solani* was heterotrophic for biotin and choline, but this assumption was not upheld when growth curves were determined (Fig. 1), and was contrary to the report of Newton (8). The time of 3 to 4 days for growth had been chosen prior to growth curve experiments because yeast extract had produced good growth in this length of time. With the construction of growth curves it was evident that there were no obligate vitamin requirements for *Alternaria solani*. It was also evident that the 3 vitamins, biotin, choline, and thiamine, were not produced by the fungus at a

[1]Accepted for publication August 5, 1952.
Paper No. 41 from the Department of Biological Science, Michigan State College.

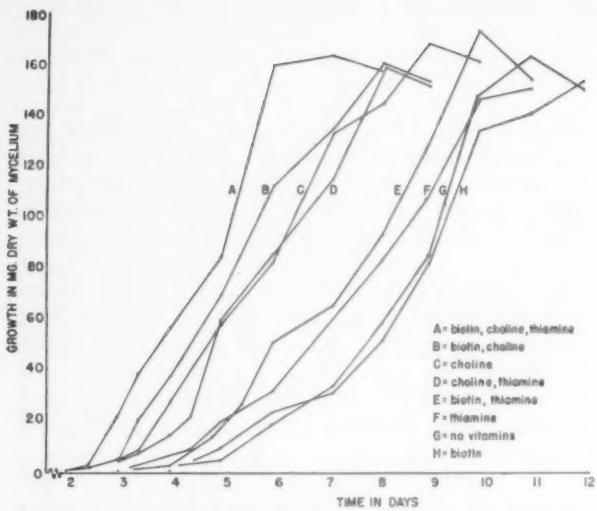


FIG. 1. Growth curves of *Alternaria solani* when grown on inorganic foods and glucose plus the vitamins as indicated on the graph. The lower portions of some of the curves were omitted.

fast enough rate so that the other potentialities for growth were realized.

In the growth curves of Fig. 1 it can be seen that the vitamins do not increase the maximum growth possible on the basal medium. This held true in all growth curve experiments and the maxima did not deviate 10 mg. above or below the 160 mg. average. The vitamins did, however, greatly reduce the stationary and lag phases of the curves. In experiments when a complete set of curves were determined simultaneously, the biotin-choline-thiamine medium caused most rapid growth (Fig. 1, curve A), the biotin-choline medium was next (curve B), and the basal medium was usually slowest (curve G). The other curves were more "susceptible" to undetermined factors and changed their positions within the limits, at half maximum growth, of curves B and H.

Experiments of 3 days duration were conducted, using biotin, choline, and thiamine, in order to determine the effect of varying the concentration of 1 of the vitamins while the other 2 were kept constant. The results are in Fig. 2. The minimum level which had a pronounced effect on growth was for biotin, 0.00005 mg. per 1.; for choline, 0.1 mg. per 1.; and for thiamine, 0.0025 mg. per 1. These data indicate that the basal medium was free of these 3 vitamins because the levels which caused a strong growth response were at or below the assayable limits of these substances.

Aside from biotin and choline as depicted in Fig. 2, PAB was the only vitamin tested that caused a marked inhibition. For example, in one experiment growth on basal medium plus biotin, choline, and thiamine was 59 mg. and when PAB was added growth was 38 mg. In another experiment PAB partially inhibited growth on basal medium and growth on basal plus choline, on basal plus biotin and choline, and on basal plus biotin, choline, and thiamine.

It is well known that choline participates in trans-

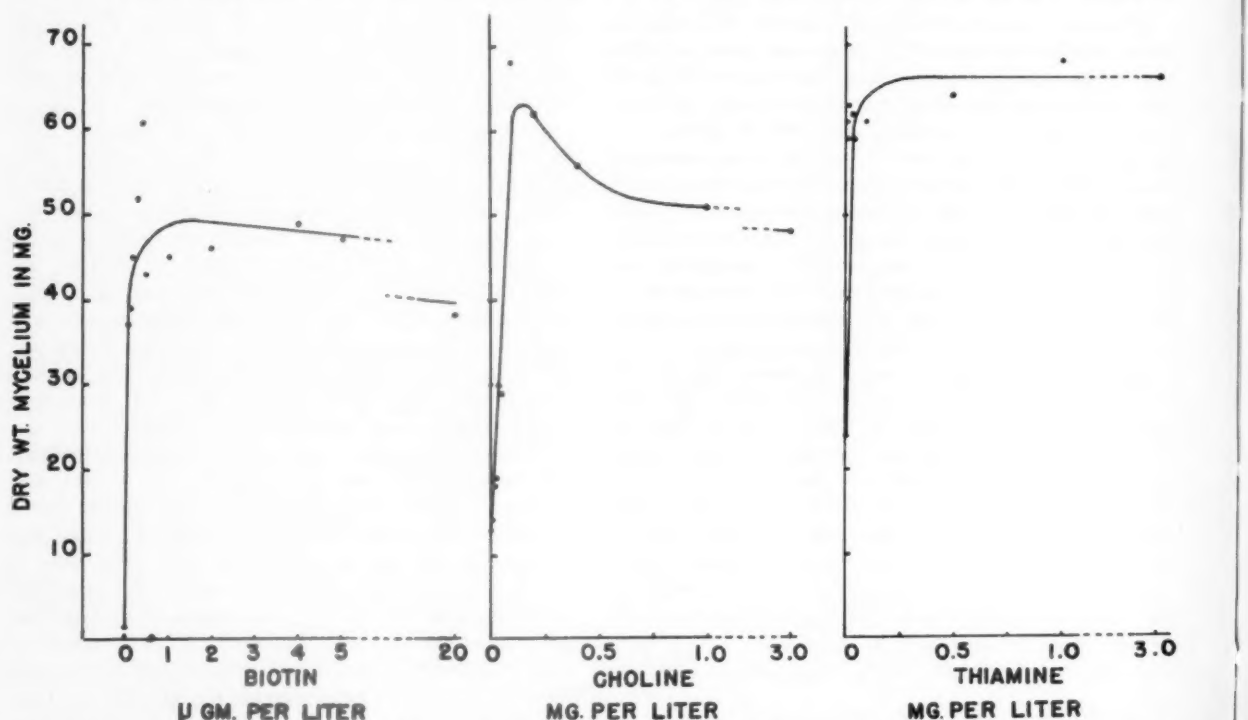


FIG. 2. Growth of *A. solani* as affected by varying amounts of 1 vitamin while the other 2 were held constant at the following concentrations in mg. per liter: biotin, 0.005; choline, 2.0; and thiamine, 1.0.

methylations and that there are several substances that are related to it in metabolism (6). In one experiment to test some of these, the various substances were added to basal medium plus biotin and thiamine. Growth in mg. is as noted for each of the following substances added: none, 2; 1 mg. betaine per flask, 41; 1 or 10 mg. creatine, 1; 1 or 10 mg. ethanolamine, 1 and 3 respectively; 1 mg. beta dimethylaminoethyl alcohol, 32. Methionine was tested alone and in combination with B_{12} and folic acid. The experiments were terminated at 3 days. Methionine had no effect alone or with 1 or both of the vitamins.

A faster rate of growth than that attained on basal medium plus biotin, choline, and thiamine was not realized by the addition of yeast extract (10, 100, or 1000 mg. per litre) or any of the vitamins listed above. If, however, acid hydrolyzed casein, malt extract, or peptone were added, growth was greater at the end of 3 days. The amount added to each flask and the mg. of mycelium in one experiment were as follows: nothing 56, 5 mg. acid hydrolized casein 64, 1 mg. malt extract 63, 1 mg. peptone 67, and 10 mg. peptone 73.

Discussion.—The paper of Dewey, Parks and Kidder (4) is worthy of careful consideration in relation to the nutrition hypothesis. They have found with *Tetrahymena gelii*, that large increases in growth can be brought about by disproportionately increasing the concentration of foods present in their one-time best synthetic medium. If this proves to be true for *Alternaria solani*, and there is no reason to expect that it will not be, it seems reasonable to predict that the susceptibility of its host is determined in part by the presence and the proportions of the necessary foods and in part by the interactions between these positive factors and the various negative factors which are present at the same time. A complete analysis of this problem in this more simple situation found in plant pathology should make possible generalizations of significance in the whole field of parasitism.

SUMMARY

Alternaria solani has no obligate vitamin requirements. Under the conditions tested biotin, choline, and thiamine considerably increase the rate of growth. Choline has a more pronounced effect than the other 2. Betaine and beta dimethylaminoethyl alcohol can substitute for choline while methionine cannot.

Department of Biological Science
Michigan State College
East Lansing, Michigan

LITERATURE CITED

1. Bacon, G. A., I. W. Burrows, and M. Yates. 1951. The effects of biochemical mutation on the virulence of Bacterium typhosum: the loss of virulence of certain mutants. Brit. Jour. Exp. Pathology **32**: 85-96.
2. Beadle, G. W. and E. L. Tatum. 1945. Neurospora II. Methods of producing and detecting mutations concerned with nutritional requirements. Amer. Jour. Bot. **32**: 678-686.
3. Brown, W. 1948. Physiology of the facultative type of parasite. Proc. Roy. Soc. (London) Ser. B. **135**: 171-179.
4. Dewey, V. C., R. E. Parks and G. W. Kidder. 1950. Growth responses of Tetrahymena gelii to changes in the basal media. Arch. Biochem. **29**: 281-290.
5. Gaumann, E. 1950. Principles of plant infection. p. 270. Trans. by W. B. Brierley. Hafner Publishing Co., N. Y.
6. Horowitz, N. H., D. Bonner and M. Houlahan. 1945. The utilization of choline analogues by cholineless mutants of Neurospora. Jour. Biol. Chem. **159**: 145-151.
7. Lewis, R. W. 1948. Mutants of Neurospora requiring succinic acid or a biochemically related acid for growth. Amer. Jour. Bot. **35**: 292-295.
8. Newton, W. 1946. The growth of Sclerotinia sclerotiorum and Alternaria solani in simple nutrient solutions. Sci. Agric. **26**: 303-304.

THE INHERITANCE OF RESISTANCE TO FROG-EYE LEAF SPOT OF SOYBEANS[1]

Kirk Athow and A. H. Probst[2]

Frog-eye leaf spot incited by *Cercospora sojina* Hara was first observed in Indiana in 1939 in the extreme southwestern part of the state by A. H. Probst and identified by R. M. Caldwell of the Purdue Agricultural Experiment Station. The disease was of minor importance until 1947 when it occurred in epiphytotic proportions in the large soybean growing area of southwestern Indiana. It continued as the most important soybean disease through the 1949 season after which its incidence was reduced greatly by widespread use of the resistant varieties Lincoln and Wabash.

In Indiana, prior to 1949, frog-eye was confined to the southern part of the state. However, in 1949 it was observed as far north as Lafayette and in 1950 was found on the variety Hawkeye in small amounts even in the northern third of the state. The rapid spread of the disease and the large acreage of the Hawkeye variety now grown makes this a potentially important disease throughout the state and stresses the need for its control. Results of a study to determine the inheritance of resistance are reported here.

Review of literature.—The fungus causing frog-eye was described as *Cercospora sojina* by Hara (1) in Japan in 1915. In 1921 Miura (4) in a brief mycological note published a description of a Cercospora leaf spot disease of soybean which he found at Tumenling in southern Manchuria. He evidently was not aware of the earlier report by Hara because he ascribed it to a new fungus which he named *Cercospora daizu*. In the United States both species names have been used; *daizu*, commonly mispelled *diazu*, appears more frequently.

According to Lehman (3) and Melchers (5), Moore recorded the occurrence of a Cercospora on soybean in South Carolina in 1924. This probably was the first published report of frog-eye leaf spot on soybean in the United States.

Haskell (2) and Lehman (3) reported that in 1925 J. L. Weimer collected specimens of a soybean leaf spot at Clemson and Orangeburg, S. C., Starkville, Mississippi, and Baton Rouge, Louisiana. In 1926 Moore again collected specimens of a Cercospora leaf spot on soybean from a section of South Carolina remote from Clemson. Representative specimens of the 1925 collection by Weimer in South Carolina and the 1926 collection by Moore were examined by Lehman (3) and identified as frog-eye leaf spot.

According to Haskell (2), C. W. Edgerton reported the occurrence of Cercospora leaf spot on soybean in Louisiana and gave 1925 as the first year in which the disease had been observed there.

Frog-eye on soybean was first seen in North Carolina by Lehman (3) in 1925 and reported by Wolf and Lehman (6) in 1926 as identical with that found by Miura in Manchuria.

In 1929 Lehman (3) gave a complete description of the disease and the causal organism. He reported that early maturing varieties such as Dixie, Manchu, and Virginia escape serious injury while late maturing varieties such as Otootan and Biloxi suffered more severely.

Since 1929 the disease has been reported at various times from Alabama, Arkansas, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Louisiana, Maryland, Mississippi, Missouri, New York, North Carolina, Ohio, Oklahoma, South Carolina, and Virginia. It occurs most commonly in the southern part of the United States. It also has been reported from Australia, Canada, China, Germany, Japan, Manchuria, and Russia. None of the reports has dealt with the inheritance of resistance.

A marked difference in susceptibility to frog-eye was noted among the varieties grown in southwestern Indiana in 1949. Field observations indicated that the varieties Lincoln and Wabash had a high degree of resistance, whereas Gibson, Patoka, and Hawkeye were very susceptible. Chief and Perry were somewhat less susceptible. Inoculations in the greenhouse confirmed these field observations. The disease reactions of the fungus on 5 soybean varieties grown in southwestern Indiana are shown in Figure 1. The difference between the susceptible and less susceptible varieties was in number of lesions per plant rather than size of lesion or abundance of sporulation. The resistant varieties, Lincoln and Wabash, had only occasional spots and these were often small and nonsporulating.

Materials and methods.—F_2 seed of crosses Lincoln × Gibson, Lincoln × Chief, Lincoln × Hawkeye, Lincoln × Patoka, Patoka × Wabash, Perry × Lincoln, and Chief × Hawkeye were obtained from L. F. Williams of the U. S. Regional Soybean Laboratory, Urbana, Illinois. The F_2 seed from individual F_1 plants of each cross and 4 plots of each parent variety were randomized completely in rows. These were planted between rows planted with frog-eye infected seed of the variety Gibson at Evansville, Indiana. Ex-

[1]Accepted for Publication July 14, 1952.
Contribution from the Department of Botany and Plant Pathology and the Department of Agronomy, Purdue University Agricultural Experiment Station, Lafayette, Indiana, and the U. S. Regional Soybean Laboratory, Division of Forage Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, cooperating. Journal Paper No. 597, Purdue University Agricultural Experiment Station. Journal Paper No. 226, U. S. Regional Soybean Laboratory.

[2]Assistant Pathologist, Purdue Agricultural Experiment Station and Agent (Assistant Pathologist), Division of Forage Crops and Diseases, and Associate Agronomist, Division of Forage Crops and Diseases, respectively.

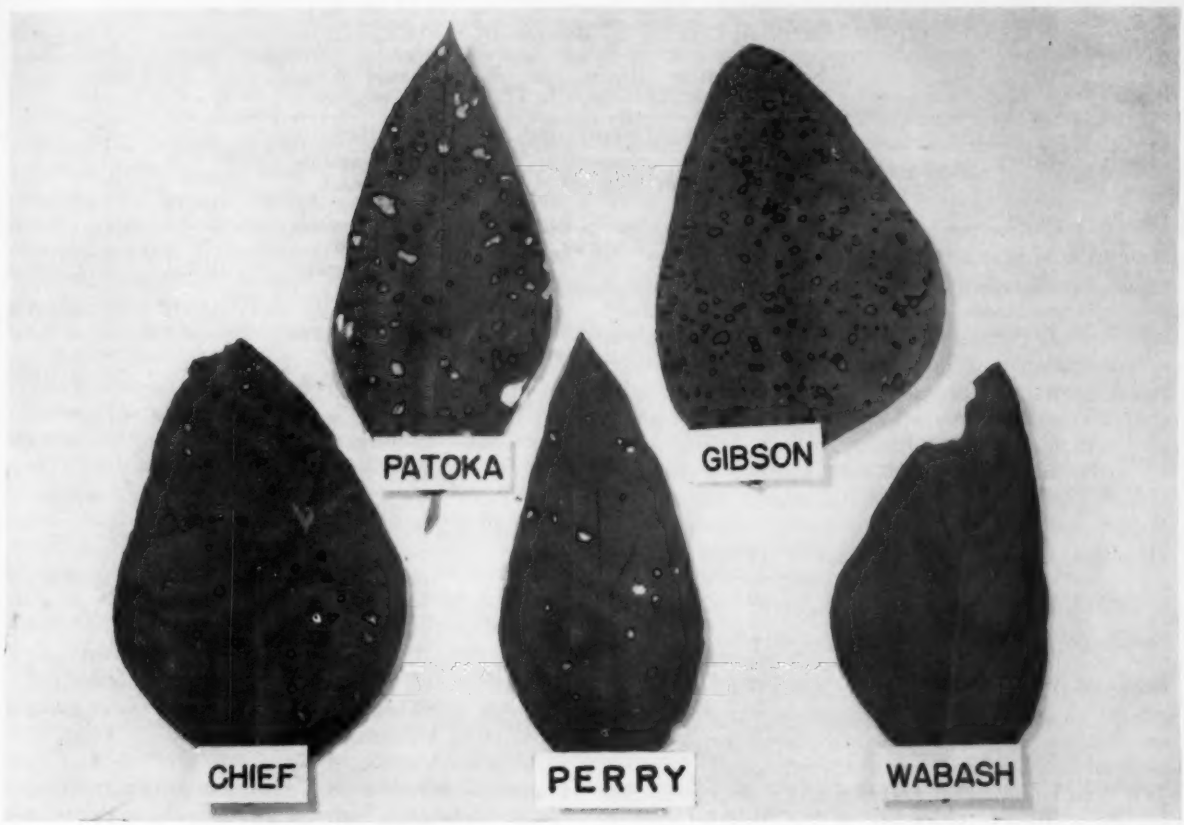


FIG. 1. Natural frog-eye leaf spot infection on 5 soybean varieties grown at Evansville, Indiana, in 1950. Hawkeye and Lincoln, not shown in Fig. 1, are similar in reaction to Patoka and Wabash respectively.

cellent natural infection was obtained throughout the nursery.

EXPERIMENTAL RESULTS.—F_2 segregation of all crosses is shown in Table 1. Since the chi-square test indicated no significant difference between the progeny of each F_1 plant within crosses, the data for each cross were combined. A satisfactory fit to a 3:1 ratio was obtained in the F_2 progeny of each resistant × susceptible cross indicating that the resistance of Lincoln and Wabash was conditioned by a single major dominant factor. The symbols Cs, cs have been assigned to this gene pair. Progeny of the cross Lincoln × Wabash was not studied, so it is not known whether resistance in these 2 varieties is controlled by the same gene. All but 9 of the F_2 progenies of Chief × Hawkeye (both susceptible) were susceptible. Seed mixture probably was responsible for the occurrence of the 9 resistant plants from a total population of 208 F_2 plants obtained from 3 F_1 plants 1 of which had no resistant segregates.

Susceptible and resistant F_2 selections were made in 1950 and F_3 progeny rows were grown in 1951 to verify the hypothesis of a single gene segregation.

The F_3 progeny behaved as would be expected if resistance was controlled by a single factor (Table 2, part A). The susceptible F_2 plants were homozygous for susceptibility in all crosses. The resistant F_2 plants segregated in a ratio of 1 homozygous : 2 heterozygous

TABLE 1.—*Segregation for reaction to Cercospora sojina in the F_2 populations of 7 crosses under conditions of natural infection*

Parentage	Distribution of F_2 plants			3:1 ratio	
	Total	Resistant	Susceptible	χ^2	P
	No.	No.	No.		
Lincoln × Gibson	358	261	97	0.8380	0.50-0.30
Lincoln × Chief	409	300	109	0.5941	0.50-0.30
Lincoln × Hawkeye	150	103	47	3.2089	0.10-0.05
Lincoln × Patoka	175	121	54	3.2019	0.10-0.05
Patoka × Wabash	1032	790	242	1.3230	0.30-0.20
Perry × Lincoln	64	44	20	1.3333	0.30-0.20
Chief × Hawkeye	208	9	199	——	——

TABLE 2.—*Breeding behavior of F_3 progeny of 6 soybean crosses to Cercospora sojina*

Parentage	No. F_2 plants tested	Reaction to Cercospora in F_2	Behavior of the F_3 progeny	1:2 ratio χ^2	1:2 ratio P
A. Progeny from random F_2 plants					
Lincoln × Gibson	13	Susceptible	All susceptible		
	33	Resistant	18 resistant		
			15 segregating	6.6818	<0.01
Lincoln × Chief	7	Susceptible	All susceptible		
	14	Resistant	3 resistant		
			11 segregating	0.8928	0.50-0.30
Lincoln × Hawkeye	9	Resistant	4 resistant		
			5 segregating	0.5000	0.50-0.30
Lincoln × Patoka	9	Susceptible	All susceptible		
	34	Resistant	15 resistant		
			19 segregating	1.7794	0.20-0.10
Patoka × Wabash	14	Susceptible	All susceptible		
	42	Resistant	17 resistant		
			25 segregating	0.9643	0.50-0.30
Perry × Lincoln	20	Susceptible	All susceptible		
	39	Resistant	23 resistant		
			16 segregating	11.5385	<0.01
B. Progeny from selected F_2 resistant plants					
Lincoln × Gibson	17	Resistant	5 resistant		
			12 segregating	0.1176	0.80-0.70
Lincoln × Chief	40	Resistant	13 resistant		
			27 segregating	0.0125	0.95-0.90
Lincoln × Patoka	6	Resistant	2 resistant		
			4 segregating	0.0000	1.00
Patoka × Wabash	153	Resistant	60 resistant		
			93 segregating	2.3824	0.20-0.10

resistant in all crosses except Lincoln × Gibson and Perry × Lincoln. These gave a poor fit to a 1:2 ratio. This poor fit was probably a result of misclassification in the F_3 rows rather than in the F_2 plants. This hypothesis appears most likely because excellent, uniform infection was obtained in the F_2 planting in 1950, but only moderate to fair infection was obtained in the F_3 plant rows in 1951. Also, poor emergence in some cases resulted in a small number of plants per F_3 row, and 1 or 2 susceptible plants might have escaped infection.

An additional 216 resistant F_2 plants with desirable agronomic characters were selected from the crosses Lincoln × Gibson, Lincoln × Chief, Lincoln × Patoka, and Patoka × Wabash. The F_3 progenies were grown in plant rows for further testing and selection. A good fit to a ratio of 1 homozygous : 2 heterozygous resistant plants was obtained in all crosses, (Table 2, Part B), including the Lincoln × Gibson cross which gave a poor fit in the material mentioned above. No additional material of the cross Perry × Lincoln was available for checking in the selection nursery.

SUMMARY

The F_2 segregation in 6 crosses of resistant × susceptible soybean varieties was studied under conditions of natural infection to *Cercospora sojina*, the causal fungus of frog-eye leaf spot. Resistance in the crosses studied was found to be due to a single major dominant Mendelian factor. The symbols Cs, cs have been assigned to this gene pair.

PURDUE AGRICULTURAL EXPERIMENT STATION
LAFAYETTE, INDIANA

LITERATURE CITED

1. HARA, K. 1915. Spot disease of soybean. Agr. Country **9:** 28. (In Japanese).
2. HASKELL, R. J. 1926. Disease of cereal and forage crops in the United States in 1925. U. S. Dept. Agr. Pl. Dis. Rept. Supl. **48:** 375-376.
3. LEHMAN, S. G. 1928. Frog-eye leaf spot of soybean caused by Cercospora diazu Miura. Jour. Agr. Res. [U. S.] **36:** 811-833.
4. MIURA, M. 1922. Diseases of the main agricultural crops of Manchuria. Bul. So. Manchuria Railway Co., Koshurei; Agr. Expt. Sta. Manchuria **11:** 1-56. 1921 (In Japanese) English abstract in Japan Jour. Bot. **1:** (1) : 1.
5. MELCHERS, L. E. 1925. Diseases of cereal and forage crops in the United States in 1924. U.S. Dept. Agr. Pl. Dis. Rept. Supl. **40:** 186.
6. WOLF, F. A. AND S. G. LEHMAN. 1926. Diseases of soybeans which occur in both North Carolina and the Orient. Jour. Agr. Res. [U. S.] **33:** 391-396.

STUDIES ON THE NATURE OF THE SPECIFIC TRANSMISSION OF ASTER-YELLOWS AND CORN-STUNT VIRUSES[1]

Karl Maramorosch

Very little is known about the fate of plant viruses acquired by nonvector insects. What happens to a virus ingested by a nonvector leafhopper? Why can insects, apparently feeding in a similar manner on a susceptible plant, transmit one, but not another virus? Evidence for multiplication of several leafhopper-transmitted viruses in their respective vectors has accumulated in the past 2 decades and was recently reviewed by Black (4). Multiplication in insects adequately explains the incubation period and the retention of viruses. The principal scope of this investigation was to gain evidence for the working hypothesis that vector specificity is mainly due to the ability of a given virus to multiply only in certain vector-insects. Specifically, it was aimed to find whether or not the differential transmission of aster-yellows and corn-stunt viruses by certain vectors could be explained on the basis of virus multiplication in vectors and lack of it in the nonvectors. So far as the author is aware, it is the first experimental attempt of this kind.

Several other incidental problems that arose were investigated. The possibility of transferring the corn-stunt virus in a serial passage experiment in its vector was studied; tests were made to detect a possible inhibitory effect of nonvector juices on the 2 viruses; the recovery of the viruses from the nonvector leafhoppers was attempted; an attempt was made to permit nonvector insects to transmit by puncturing their gut walls. Preliminary reports on 2 stages of the work have been published (15, 16).

LITERATURE.—The viruses of aster-yellows and corn-stunt are typical yellows viruses and their symptoms in affected plants and similarity in biological transmission indicate that they may be somewhat closely related. Their relationship to their insect vectors, the aster leafhopper *Macrosteles divisus* Uhler (7) and the corn leafhopper *Dalbulus maidis* DeL. and Wol. (9), is characterized by an incubation period of considerable length and retention of the virus (8, 10).

Storey transmitted corn-streak virus mechanically to the vector *Cicadulina mbila* Naude (19). He also tried to render other insects infective by means of injections and demonstrated the presence of virus in *Peregrinus maidis* Ashm., but obtained no transmission. Bennett and Wallace (1) found curly-top virus of sugar beets in several species of insects, which were unable to transmit it to plants. Maramorosch (13) transmitted aster-yellows virus in 10 serial passages through the aster leafhopper, using insect injections. By the same techinique corn-stunt virus was mechanically transmitted to the corn leafhopper (12). The aster and corn leafhoppers are closely related (18) and belong to the same tribe *Macrostelini* of the subfamily *Deltocephalinae*, fam. *Cicadellidae*. The relationship of the 2 vectors and the resemblance of the 2 viruses determined their choice for the proposed tests.

MATERIALS AND METHODS.—Aster-yellows virus for all tests was obtained from China asters (*Callistephus chinensis* Nees), grown from commercial seed of the Shell Pink variety and infected experimentally in a greenhouse by means of leafhoppers. Virus-free *Macrosteles divisus* were reared in an insectary on rye (*Secale cereale* L.) plants, immune from aster yellows. When viruliferous leafhoppers were desired for tests or as sources of virus, usually 100 nymphs or adults from stock cultures were fed on diseased asters for 2 weeks and later maintained for an additional 2 weeks on rye plants. The term "viruliferous" was used to describe insects which acquired virus by feeding or injection irrespective of whether or not they were able to transmit. Transmitting insects were designated as "infective" (11).

The corn-stunt disease has been maintained in New York since 1949 in a greenhouse on corn (*Zea mays* L.) plants, inoculated by means of *Dalbulus maidis*. A stock colony of virus-free corn leafhoppers was reared in an insectary and routinely checked for freedom from virus. The insectary for corn and aster leafhoppers was devised by Dr. L. O. Kunkel when the greenhouses were built in New York. A glass wall separated the 2 parts and doors at opposite ends of a greenhouse led to the 2 breeding places. This provision facilitated breeding of large numbers of 2 species of leafhoppers with the least chance of contaminating a colony.

Viruliferous corn leafhoppers were obtained by permitting insects in the nymphal stage to feed on a portion of a diseased leaf or whole plant for from 1 to 3 days, and subsequently transferring them at weekly intervals to fresh corn plants for 6 weeks or longer. During this period the insects became adults and the incubation period was completed.

The question of whether or not any given virus multiplies in an insect could be tested experimentally by a serial passage with proper dilution of the inoculum. This method, described earlier in detail (13), was employed to test whether or not aster-yellows and corn-stunt viruses could multiply in each other's vectors.

Preliminary tests indicated that a temperature of 25° C. was suitable for experiments with aster-yellows virus, whereas 30° C. was more advantageous for corn-stunt virus. Therefore insects with aster-yellows and corn-stunt virus were kept at 25° C. and 30° C., respectively, in temperature control chambers described earlier (13).

EXPERIMENTS AND RESULTS.—*Transmission tests with nonvector insects.*—Kunkel (10) demonstrated that *Macrosteles divisus* was unable to transmit corn-stunt

[1]Accepted for publication August 19, 1952.

virus. In view of the earlier work of Storey with corn streak (19), an attempt was made to render aster leafhoppers infective by puncturing their gut walls. Fifty virus-free aster leafhoppers were caged for 1 week on a stunted corn plant. On the seventh day the insects were removed, immobilized by exposure at 0° C. in a coldroom and punctured with sterile No. 00 insect pins. Subsequently the leafhoppers were warmed up to room temperature, caged on 5 aster plants at 30° C., and transferred in the following manner. Every week they were allowed to feed on fresh healthy aster plants for the first 4, and on corn plants for the following 3 days. After 5 weeks the number of surviving insects was reduced to 1, 1, 3, 2, and 1, respectively, in the 5 cages. After an additional, sixth, week following the puncturing, the experiment was discontinued with but 2 surviving insects. After exposure aster plants were discarded, and 27 corn plants observed in a greenhouse for 3 months. No transmission of corn stunt was obtained with wounded aster leafhoppers.

Attempts to transmit aster-yellows virus by means of corn leafhoppers were made with punctured as well as nonpunctured corn leafhoppers. Out of 50 *D. maidis* adults and nymphs from virus-free stock, 48 survived a 7-day feeding period on diseased aster plants. The group was then divided into 2 lots of 24 insects and 1 lot was wounded by means of insect pins. Both lots were caged on corn plants at 25° C. for 3 weeks. Subsequently the insects were kept alternately for 2 days on aster plants and for 5 days on corn plants. After 3 weeks the experiment was terminated. Seventy-two exposed aster plants were observed in a greenhouse for 6 weeks. No transmission of aster-yellows by *D. maidis* was obtained.

In the transmission attempts with nonvector insects, controls consisted of equal numbers of noninoculated aster and corn plants, respectively, for each set of test plants. All controls remained healthy. No control insects were tested, as their freedom from viruses for which they were potential vectors was ascertained in simultaneous routine tests of the stock. Alternating feeding on corn and aster plants was especially important in the case of corn leafhoppers which prefer feeding on corn to any other plant tested so far (10) and which would die within a few days if kept continuously on asters.

Recovery of virus from nonvector species.—An attempt was made to recover aster-yellows and corn-stunt viruses from nonvector species. The aster-yellows virus was introduced into some *D. maidis* by feeding on diseased asters for 2 days and into others by injection of juices from infective aster leafhoppers. After the 2-day feeding on diseased plants or after the injection, viruliferous corn leafhoppers were caged on corn plants. Aster-yellows virus was also introduced by 2-day feeding on diseased asters into *Agallia constricta* Van Duzee, kindly supplied by Dr. L. M. Black. Corn-stunt virus was introduced into some aster leafhoppers by feeding on stunted corn plants for 2 days, and into others by injection of juices from infective corn leafhoppers. Insects of the 3 species, whether inoculated by feeding or by injection, were divided into 2 groups. The first group was macerated 2 days after inoculation, and the diluted juices injected into vector species. The second group was similarly tested 19 days later. All dilutions were 1:100 by weight, with neutral buffered 0.25 M NaCl. Fifty leafhoppers were injected in each of the 10 groups and the survivors tested in small groups as long as they lived. Results of these tests are in Table 1. They showed that aster-yellows virus could be recovered from clover leafhoppers after 21 days, but not after 2 days. It could be recovered from fed but not from injected corn leafhoppers after a period of 21, but not after 2 days. The corn-stunt virus could be recovered from fed but not from injected

TABLE 1.—*Recovery of aster-yellows and corn-stunt viruses from nonvector leafhoppers. Tests for the presence of viruses were made by injection of vector species with juices from nonvectors*

Virus	Nonvector leafhopper species	Time of maceration[a]	Transmission record of injected vector species Colonies of 1 to 3 insects transferred at weekly intervals[b] Weeks: 1	2	3	4	5	6	7	8	9
Virus acquired by nonvectors in 2-day feeding on diseased plant											
Aster yellows	*Agallia constricta*	A	0/5	0/5	0/5	0/4	0/3	0/3	0/1	–	
		B	0/5	0/5	2/4	3/4	2/3	1/2	1/1	–	
Aster yellows	*Dalbulus maidis*	A	0/4	0/4	0/4	0/4	0/3	0/3	0/1	–	
		B	0/5	0/5	3/5	3/5	3/5	2/4	1/2	–	
Corn stunt	*Macrosteles divisus*	A	0/5	0/5	0/5	0/5	0/4	0/4	0/4	0/4	0/2
		B	0/6	0/6	0/6	0/6	2/6	3/6	2/5	2/4	2/3
Virus acquired by nonvectors through injection			Colonies of 1 to 5 insects								
Aster yellows	*Dalbulus maidis*	C	0/9	0/8	0/6	0/5	0/3	0/1	–		
		D	0/10	0/7	0/4	0/4	0/3	0/2	–		
Corn stunt	*Macrosteles divisus*	C	0/8	0/7	0/5	0/5	0/4	0/3	0/2	0/2	0/1
		D	0/9	0/6	0/6	0/5	0/3	0/2	0/1	–	

[a]Time of maceration A) After 2-day feeding on diseased plants; B) 19 days after removal from diseased plants; C) 2 days after injection; D) 21 days after injection.

[b]The numerator denotes the number of positive tests (infected plants) and the denominator the total number of tested plants.

TABLE 2.—*Serial passage of corn-stunt virus in Dalbulus maidis by means of insect injections*

Passage no.[a]	Transmission record of injected insects transferred individually once every week to fresh plants[b] Weeks						Total of exposed plants	Total of infected plants	Control insects[c] 1st week	Control insects[c] 6th week
	1	2	3	4	5	6				
1	0/50	0/31	0/26	0/21	1/17	3/17	112	4	0/50	0/29
2	0/50	0/39	0/32	0/26	4/25	6/18	114	10	0/50	0/32
3	0/50	0/32	0/29	0/24	0/20	2/17	122	2	0/50	0/41

[a]Diluted juices from 20 viruliferous insects were used as source of virus for the first group. The inoculum for the second and third group was obtained by maceration and dilution to 1:100 of all insects of the first and second group, respectively, which survived 30 days.
[b]The numerator denotes the number of infected plants, the denominator the total number of tested plants.
[c]The numerator denotes the number of infective insects, the denominator the total number of tested insects.

aster leafhoppers, also, after a period of 21 but not after 2 days.

Serial passage of corn-stunt virus in Dalbulus maidis.—The possibility of propagating the aster-yellows virus in injected *Macrosteles divisus* has been demonstrated by means of a serial passage experiment by Maramorosch (13). Recently Black and Brakke (5) transmitted wound-tumor virus in serial passage to 7 groups of injected clover leafhoppers. It was assumed that the corn-stunt virus, which could be transmitted mechanically to insects by injections, would also be suitable for serial passage tests.

The source of virus was obtained by feeding 30 *D. maidis* nymphs on stunted corn plants for 1 week and maintaining them for an additional 6 weeks on corn plants. Twenty adult insects were then macerated, diluted to 1:100 and centrifuged for 5 minutes at 3500 r.p.m. Measured amounts of 1/8000 cc. were injected into 50 virus-free corn leafhoppers. After 6 weeks, during which individual insects were transferred once every week to fresh plants, 12 surviving insects of the first group were macerated and the juice diluted and centrifuged and used as inoculum for a new group of virus-free insects. The survival of insects during consecutive weeks of transmission tests is shown in Table 2. Survivors of the second passage were used as a source of inoculum for the third group. After 6 weeks of testing, 15 remaining insects of the third passage were discarded. Controls for each passage consisted of 50 non-injected insects from stock, tested on an equal number of plants and transferred on the same days as the injected leafhoppers. The control insects were tested individually only during the first week after the injection of each inoculated group. Later, when the number of inoculated insects decreased, controls were tested in groups of from 2 to 4 insects, but the number of plants exposed every week was equal to the number of plants on which inoculated insects fed. Some injected leafhoppers in all 3 groups became infective. All controls proved virus-free. The comparatively small number of insects rendered infective in each group may have resulted from the time limit of 6 weeks in each passage. The shortest incubation period of corn-stunt virus in injected insects was determined as approximately 6 weeks (12). The serial passage confirmed the assumption that corn-stunt virus could be carried in its vector in serial passage by means of injections. It was not aimed to demonstrate the multiplication of the virus in the vector; therefore the dilutions at each transfer were only 1:100 and after 3 transfers the experiment was terminated.

Attempted serial passage of aster-yellows virus in Dalbulus maidis.—Having established that corn-stunt and aster-yellows virus could be carried in series in vector insects, serial transfer of each of these 2 viruses was attempted in the vector of the other. Although previous tests showed that viruses introduced by injection into nonvectors could not be recovered directly, it was assumed that these viruses might perhaps increase in titer during passage, and thus permit recovery. Such an increase in titer was described recently by Casals *et al.* (6) for the poliomyelitis virus in mice. The tests, described separately below, were started simultaneously in the summer of 1951. Ninety viruliferous *M. divisus* were kept for 4 weeks on diseased aster plants at 25° C. before maceration. Their juice diluted to 1:100 was injected into virus-free *D. maidis* (Table 3). The inoculated insects of each of the first 3 groups were kept at 25° C. for 30 days and transferred at weekly intervals to fresh corn plants. The inoculum for each group was diluted to 1:100 by weight. Survivors of the third group were used for the attempted recovery of the virus. After maceration and dilution their centrifuged juices were inoculated into 50 aster leafhoppers from virus-free stock. Inoculated *M. divisus* were individually tested twice a week on individual fresh aster plants. Altogether 209 plants were exposed and later observed in a greenhouse for 6 weeks. All remained healthy. Fifty insects from stock served as controls for each passage. Once a week they were transferred in groups of 5 to fresh plants and all proved virus-free. It was concluded that aster-yellows virus either did not multiply in the corn leafhopper at all, or, if limited multiplication occurred, that it was insufficient for recovery by the serial passage technique.

Attempted serial passage of corn-stunt virus in Macrosteles divisus.—Viruliferous *Dalbulus maidis* were obtained by feeding leafhoppers for 1 week on

TABLE 3.—*Attempted serial passage of aster-yellows virus in three groups of Dalbulus maidis by means of injections*

Passage no.[a]	Total of injected insects[b]	Survivors after 30 days	Control
		(3 blind passages)	
1	50	21	–
2	50	14	–
3	80	17	–
(Test for recovery of aster-yellows virus, in *M. divisus*)			
4	50[c]	14	50[d]

[a]Original virus obtained from 90 viruliferous aster leafhoppers. Survivors of third group provided the inoculum for the vector species *M. divisus*.

[b]Injected corn leafhoppers were transferred at 25°C once every week to fresh corn plants. After 30 days all survivors were macerated, diluted to 1:100 and used as inoculum for the next passage.

[c]The 50 *M. divisus* were transferred twice every week, individual insects to individual young plants. The numbers of insects at successive transfers were: 50, 26, 22, 20, 19, 15, 14, 8, 8, 7, 6, 6, 4, 3, 1. Altogether 209 plants were exposed in 59 days; all remained healthy.

[d]Control insects were tested for 7 weeks on 35 plants, all remained healthy.

stunted corn and maintaining them for the following 6 weeks on corn plants at 30° C. Juices from 20 insects were diluted to 1:100 and centrifuged. The supernatant fluid was used as inoculum for 50 virus-free *M. divisus*. Inoculated insects (Table 4) were kept on asters at 30° C. for 30 days and survivors of each group were used for making inoculum for the next passage. In the fourth passage, this time in the proper vector *D. maidis*, 100 insects were inoculated and another 100 from the same stock set up as controls. The inoculated leafhoppers were kept on caged corn plants in a greenhouse during August and early part of September, for 30 days. Afterwards 26 survivors were tested individually on individual young corn seedlings for the remainder of their lives. The last insect died 11 weeks after injection. The tests on seedlings were performed at 30° C. Ninety plants were exposed and subsequently observed in a greenhouse for 3 months together with 90 unexposed control plants. Control insects, tested in 2 large lots on 22 corn plants, proved virus-free. All transmission tests were negative, as no symptoms of corn stunt developed in any plant. The incubation period of the disease in the greenhouse, determined by simultaneous routine inoculations, was approximately 5 to 7 weeks. It was concluded, therefore, that corn-stunt virus either did not multiply at all in the aster leafhopper, or did not multiply to an extent which would permit its recovery in a serial passage.

Tests for possible inhibitory action of nonvector juices.—In order to gain more information on factors responsible for the inability to recover the 2 viruses from nonvector species after injection and after the attempted serial passage, experiments were designed to test the possible presence of specific inhibitors in the juices of nonvector leafhoppers. It was likely that such inhibitors, if present in sufficient amount, could account for virus inactivation in nonvector species and thus effectively prevent multiplication and transmission. It was known from earlier work by Black (2) that some insect juices exert an inhibitory effect on viruses inoculated mechanically into plants.

Sixty viruliferous *M. divisus* were divided into 2 equal lots. One lot was macerated, diluted to 1:100 and used to inoculate 50 virus-free aster leafhoppers. This group served as a test for the presence of active virus in the inoculum. Within 19 days 9 out of 21 surviving insects transmitted aster-yellows virus. The second lot was macerated together with 30 virus-free corn leafhoppers and diluted to 1:100 with saline. The solution was then left for 30 minutes at 0° C., centrifuged for 5 minutes at 3500 r.p.m., left for 1 hour at 4° C. and the supernatant fluid used for injections. Fifty inoculated *M. divisus* were caged on 2 rye plants for 3 days and later tested individually on single young aster plants at weekly intervals for 3 weeks. It was found that the addition of corn leafhopper juices had no detectable effect on aster-yellows virus, as within 13 days 4 insects became infective and after 19 days 8 out of the 16 surviving leafhoppers transmitted. Controls consisted of 30 leafhoppers from virus-free stock, tested at weekly intervals on a total of 90 plants. All non-inoculated insects proved virus-free. When the number of insects rendered infective in the 2 groups was compared as a measure of virus concentration in the inoculum (3, 5), no difference could be detected between the pure juice of viruliferous aster leafhoppers and the mixture with corn leafhopper juices.

Tests for possible inhibition of corn stunt virus by

TABLE 4.—*Attempted serial passage of corn-stunt virus in 3 groups of Macrosteles divisus by means of insect injections*

Passage no.[a]	Total of injected insects[b]	Survivors after 30 days	Control
		(3 blind passages)	
1	50	12	–
2	50	14	–
3	50	9	–
(Test for recovery of corn-stunt virus, in *D. maidis*)			
4	100	26[c]	100

[a]Original virus obtained from 20 viruliferous corn leafhoppers. Survivors of third group provided the inoculum for the vector species *D. maidis*.

[b]Injected aster leafhoppers were transferred at 30°C once every week to fresh aster plants. After 30 days all surviving insects were macerated, diluted to 1:100 and used as inoculum for the next passage.

[c]After 30 days, 26 survivors were tested individually at weekly intervals on corn seedlings. The number of insects in consecutive weeks was: 26, 21, 16, 12, 7, 4, 3, 1. Altogether 90 plants were exposed and 90 unexposed control plants were observed with the exposed ones in a greenhouse for 3 months. All remained healthy. The 100 control insects also proved virus-free.

juices of aster leafhoppers followed the same design as described for the aster-yellows virus. Fifty corn leafhoppers injected with a mixture of juices from both corn-stunt-transmitting *D. maidis* and virus-free *M. divisus*, were kept for 5 weeks on large corn plants and transferred at weekly intervals. Then 12 individual surviving insects were tested on individual corn plants every week. Three insects became infective. In a group of insects inoculated only with juices from infective corn leafhoppers, 19 survived more than 5 weeks and 5 transmitted corn stunt during 11 weeks of testing. Control insects were tested on 35 plants and all proved virus-free.

In the 2 tests performed, expressed juices of related species of nonvector insects did not inhibit infection by the aster-yellows and corn-stunt viruses in insects inoculated by injection. The recovery of virus in other tests from macerated nonvectors fed on diseased plants also indicated that nonvector insects had no virus-specific inhibitors in their blood.

Discussion.—It was postulated earlier by the author (13) that some yellows viruses were both plant and animal viruses, since they multiply in plants and insects. The evidence presented now seems to indicate that 2 of these viruses, that of aster-yellows and that of corn-stunt, either were unable to multiply in nonvector leafhoppers or multiplied to a very limited extent. If limited multiplication occurred, it was inadequate to permit recovery of the 2 viruses directly or after attempted serial passage. If the abilities of these viruses to multiply should prove to be restricted to vector species, as indicated by the tests performed, such limitation would provide an adequate explanation for their specific biological transmission. This implies that only insects which are susceptible to these viruses can become vectors. Permeability of the gut wall and other still unknown factors may also be of importance. This was indicated by the recovery of virus from insects 21 days after they acquired it by feeding, but not 2 days after such acquisition. It may be postulated that these viruses undergo a period of maturation or possibly adsorption on cells of nonvector insects, during which time they cannot be recovered. Further studies are necessary to test these and other possible assumptions.

Wounding was employed in view of the earlier experiments of Storey (19) and Merrill and TenBroeck (17) in which nonvector insects were rendered infective by puncturing. Storey explained the activation of previously inactive *Cicadulina mbila* as caused by the removal of a barrier to the virus penetration of the gut wall. Using Storey's technique, Merrill and TenBroeck enabled *Aedes aegyptii* mosquitoes to transmit the Eastern equine encephalomyelitis virus, although these mosquitoes usually transmit only the Western strain. The close relationship of strains of virus, or of insects, was probably responsible for these results. Virus multiplication was demonstrated by 17 passages of Eastern equine encephalomyelitis virus in *A. aegyptii* (17).

Merrill and TenBroeck thought that in nature nonvector mosquitoes might change into vectors due to various infections causing intestinal injury. If this occurred repeatedly a virus might ultimately become adapted to the nonvector species. It seems now from our experiments that this would be possible only in insect species in which the virus would find a suitable medium for its multiplication.

SUMMARY

Attempts to transmit the viruses causing aster-yellows and corn-stunt by means of each other's vectors, *Dalbulus maidis* and *Macrosteles divisus*, have failed. Puncturing of nonvectors, which acquired virus by feeding on diseased plants, failed to render them infective. Attempts to recover virus from nonvectors injected with corn-stunt and aster-yellows viruses were unsuccessful. On the other hand, when nonvector *D. maidis*, *M. divisus*, and *Agallia constricta* acquired viruses by feeding, recovery could be obtained by injections of their juices into proper vectors. Such recovery was obtained after 21 days, but not after 2 days, following the feeding on diseased plants. Three serial passages of corn-stunt virus in the corn leafhopper were carried out with a 1:100 dilution at each transfer. In each passage some insects became infective. Serial passage was attempted in nonvector species by means of insect injections: aster-yellows virus into *D. maidis* and corn-stunt virus into *M. divisus*. After 3 blind passages in nonvector species an attempt was made to recover the viruses by injections of proper vectors. The failure to do so was interpreted as due to the lack of, or inadequate, multiplication in nonvector species of leafhoppers. No inhibitory effect on the viruses was observed upon injection of vectors with mixtures containing virus and juices of nonvectors. The experiments indicate that multiplication in an insect is a necessary condition for specific biological transmission of the viruses tested and that multiplication may also be necessary in the case of other plant and animal viruses of similar type.

The Laboratories of the Rockefeller Institute for Medical Research
New York, New York

LITERATURE CITED

1. Bennett, C. W., and H. E. Wallace. 1938. Relation of the curly-top virus to the vector, Eutettix tenellus. Jour. Agr. Res. [U.S.] **56**: 31-51.
2. Black, L. M. 1939. Inhibition of virus activity by insect juices. Phytopathology **29**: 321-337.
3. Black, L. M. 1941. Further evidence for multiplication of the aster-yellows virus in the aster leaf hopper. Phytopathology **31**: 120-135.
4. Black, L. M. 1952. Viruses that reproduce in plants and insects. Conference on Virus and Rickettsial Classification and Nomenclature. Annals N. Y. Acad. of Sciences. (In Press)
5. Black, L. M., and M. K. Brakke. 1952. Multiplication of wound-tumor virus in an insect vector. Phytopathology **42**: 269-273.

6. Casals, J., P. K. Olitsky, and R. O. Anslow. 1951. Adaptation of a Lansing strain of poliomyelitis virus to newborn mice. Jour. Exp. Med. **94**: 111-121.
7. Kunkel, L. O. 1924. Insect transmission of aster yellows. (Abs.) Phytopathology **14**: 54.
8. Kunkel, L. O. 1926. Studies on aster yellows. Am. Jour. Bot. **13**: 464-705.
9. Kunkel, L. O. 1946. Leafhopper transmission of corn stunt. Proc. Nat. Acad. Sci. **32**: 246-247.
10. Kunkel, L. O. 1948. Studies on a new corn virus disease. Arch f. d. ges. Virusforsch. **4**: 24-46.
11. Maramorosch, K. 1950. Influence of temperature on incubation and transmission of the wound-tumor virus. Phytopathology **40**: 1071-1093.
12. Maramorosch, K. 1951. Mechanical transmission of corn stunt virus to an insect vector. Phytopathology **41**: 833-838.
13. Maramorosch, K. 1952. Direct evidence for the multiplication of aster-yellows virus in its insect vector. Phytopathology **42**: 59-64.
14. Maramorosch, K. 1952. Multiplication of aster-yellows virus in its vector. Nature (London) **169**: 194-195.
15. Maramorosch, K. 1952. Inability of aster-yellows and corn-stunt viruses to multiply in each other's vectors. (Abs.) Phytopathology **42**: 113.
16. Maramorosch, K. 1952. Recovery of aster-yellows and corn-stunt viruses from nonvector leafhoppers. (Abs.) Phytopathology **42**: 470.
17. Merrill, M. H., and C. Tenbroeck. 1935. The transmission of equine encephalomyelitis virus by Aedes aegypti. Jour. Exp. Med. **62**: 687-695.
18. Oman, P. W. 1949. The nearctic leafhoppers. A generic classification and check list. Entomol. Soc. of Washington Memoirs No. 3. 253 pp.
19. Storey, H. H. 1933. Investigations of the mechanism of the transmission of plant viruses by insect vectors. Proc. Roy. Soc. Lond. B. **113**: 463-485.

BLIGHT OF AMARANTHUS PANICULATUS L. CAUSED BY ALTERNARIA [1]

N. S. Venkatakrishnaiah

Amaranthus paniculatus L., cultivated for the seed commonly used for food in India, was observed to be infected by *Alternaria* sp. at the Government Central Farm, Hebbal, Bangalore, in December 1946. The infection was virulent on the flowers and showed slightly on leaves and stems. According to Saccardo,[2] Peck records *Macrosporium amaranthi* on the leaves of *Amaranthus retroflexus* in Kansas. There appears to be no record of any species of *Macrosporium* or *Alternaria* on any species of *Amaranthus* in India.

Infected flowers on the central spike were black and appeared as though affected by smut (Fig. 1, A, B). The mycelium invaded the bracts, sepals, stigma and ovary. Conidia and conidiophores were abundant on affected parts. The spots on the leaves (Fig. 1, A) were circular and brownish to dark brown. Lesions on the stem were irregular in shape, slightly depressed and dark. The hyphae varied from 4–8 μ in width. The conidia on the flowers were brown, with short or long septate beaks, and measured 31.5 to 71 μ by 12 to 20 μ, including the beak. They contained 3–9 transverse septa with a longitudinal septum in 1–5 cells. The beaks alone measured 10 to 41 μ and contained 1–3 septa. Conidiophores were single or fasciculate, simple or sometimes branched, geniculate, and measured 39.5–81.5 μ in length with 3–7 septa.

The infected flowers were fixed in alcohol-formalin-acetic solution (Rawlin's); microtome sections 10 μ thick were stained with Haidenhain's iron alum haematoxylin, and orange G. The presence of the mycelium was clearly observed in sections of the sepals and of the developing ovule (Fig. 1, C). Beaked conidia were abundantly borne on conidiophores.

The fungus was isolated from the infected flowers and brought into pure culture. It grew well, forming zonations on onion, potato-dextrose, and oat agars, and turned from dark green to black with age. The dense aerial growth which the mycelium formed on oat and French bean agars was chromogenic on rice and onion agars. Sporulation, while sparse in culture, was better on onion agar than on any other medium and was abundant when the agar medium was shredded. The conidia were dark green, obclavate, caudate, and 3–8 catenulate. The end cells were slightly hyaline. The conidia from onion agar cultures 8 days old measured 29.5–65 μ by 10–16 μ, including the beak, and possessed 3–8 transverse septa and 1–3 longitudinal. The greatest diameter was usually at the third or fourth cell from the base. The conidia germinated readily in 2 hours in sterile distilled water. The germ tube was seen emerging from any one of the cells.

Inoculations with single conidia cultures of the fungus on onion agar were done under aseptic conditions on the leaves and flowers of *Amaranthus paniculatus* L. raised in pots and in the laboratory garden. Conidia suspended in sterile distilled water were placed both on the upper and lower surfaces of leaves. The leaves and flowers of some of the plants were injured by pinpricks prior to inoculation. Moist cotton wads were placed on the inoculated regions and the plants were covered with bell jars. Characteristic spots, ½ to ¾ inch in diameter and showing mycelium and conidia, developed in 4–7 days on injured leaves inoculated on the lower surface. There was no infection on the upper surfaces of either the injured or uninjured leaves. The spikes with injured flowers at various stages of development were immersed in distilled water containing a

[1] Accepted for publication Sept. 13, 1952.
Thanks are due to Sri S. V. Venkatarayan, Plant Pathologist, for encouragement and valuable suggestions in the course of the work reported here.
[2] Saccardo, P. A. 1899. Sylloge Fungorum 14: 1096.

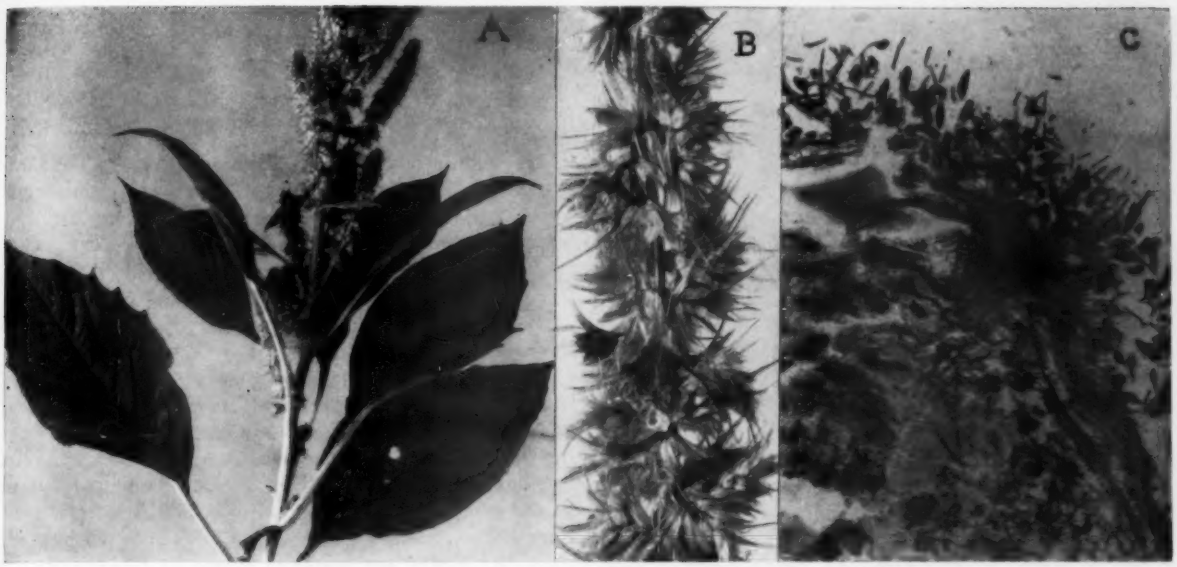


FIG. 1. A) *Amaranthus paniculatus* showing infection of *Alternaria amaranthi* on the inflorescence and on leaves; B) enlarged portion of infected spikelet, × 50; C) section of an immature fruit showing the mycelium in the ovule and perianth and the formation of the conidiophores and conidia, × 600.

heavy suspension of conidia. Some of the spikes were also atomized with the spores suspended in water. The plants were kept moist by being atomized with distilled water every day for 5 days and covered with bell jars. A few of the flowers in the potted plants took the infection in 12–15 days, turned black, and dropped; conidia and mycelium were observed in abundance. In each case the controls remained healthy. When the fungus from the infected leaves and flowers was reisolated and brought into pure culture it corresponded to the original isolate.

The conidia of *Alternaria* sp. on *Amaranthus paniculatus* closely correspond in size and shape to those of *Macrosporium amaranthi* Peck. According to Elliott[3] the species of *Macrosporium* in Saccardo's Sylloge Fungorum with obclavate spores in chains belong to *Alternaria*. Wiltshire[4] states that species of *Macrosporium* with chains of beaked conidia, as well as those forming chains only rarely, should be placed in the genus *Alternaria*. Hence the new combination **Alternaria amaranthi** (Peck) Venkatakrishniah is proposed for this fungus.

[3] Elliott, J. A. 1917. Taxonomic characters of the genera Alternaria and Macrosporium. Amer. Jour. Bot. 4: 439-476.

[4] Wiltshire, S. P. 1933. The foundation species of Alternaria and Macrosporium. Trans. Brit. Myc. Soc. 18: 135-160.

SUMMARY

Flowers and leaves of *Amaranthus paniculatus* L. were observed to be blighted by *Alternaria* sp. in Bangalore, South India. The pathogenicity of the organism was established by inoculation experiments. The conidia are comparable in size and shape to those of *Macrosporium amaranthi* Peck. on the leaves of *Amaranthus retroflexus*. The name *Alternaria amaranthi* (Peck) comb. nov. is proposed for the fungus.

PLANT PATHOLOGY SECTION,
MYSORE AGRICULTURAL DEPARTMENT
BANGALORE, INDIA

A COMPARATIVE STUDY OF TWO SPECIES OF COLLETOTRICHUM ON VETCH[1]

Norman L. Horn

Among the leguminous plants grown in Louisiana during the colder months, the vetches (*Vicia* spp.) have been widely used for soil improvement. *Vicia sativa L.*, common vetch, and *V. villosa* Roth., hairy vetch, have been the most important. Even though agronomic recommendations such as seed inoculation, adequate drainage, and application of phosphate fertilizers have been followed, many farmers have not succeeded in growing leguminous cover crops. Observations and preliminary studies indicated that diseases were in large part responsible for the poor growth and early dying of the vetches, particularly common vetch.

Preliminary studies showed that fungi belonging to the genus *Colletotrichum* were chiefly associated with foliar diseases of common and hairy vetch plants. Among the fungi reported in the literature as attacking vetch were *C. villosum* Weimer and *C. viciae* Dearn. & Overh. Since preliminary studies showed that a species of *Colletotrichum* found attacking vetch in Louisiana differed from both of these 2 previously described species in certain respects, an extensive study of this fungus was carried out. Preliminary reports have been published (4, 5).

EXAMINATION OF DISEASED PLANTS.—Both common and hairy vetch plants, showing numerous stem, pod, and leaf spots in the field, were examined in the laboratory (Fig. 1, C-D, G-I). Symptoms on leaves and stems of these plants (Fig. 1, D, H-I) were similar to those described by Weimer (8). Conidia from the spots were examined microscopically. Two distinct conidial types of *Colletotrichum* were involved, a curved conidial type (Fig. 1, A, E) and a "straight" conidial type (Fig. 1, B, F). The curved conidia were obtained most frequently from the spots on hairy vetch and the "straight" conidia most frequently from the spots on common vetch. These observations suggested existence of 2 species of *Colletotrichum* differing in pathogenicity for hairy vetch and common vetch.

Leaf spots produced by natural infection in the field were identical, so that it was not possible to distinguish the 2 types of anthracnose on the basis of plant response alone. The only means of identification was by microscopic examination of the conidia.

Observations were made of diseased field peas (*Pisum sativum* var. *arvense*), including the varieties Dixie Wonder and Austrian Winter, grown in the Louisiana Agricultural Experiment Station plots adjacent to infected common vetch. Stems and leaves exhibited spots circular to oval in shape and dark green. Diseased plant material was placed in a moisture chamber for several days when some of the fungi produced conidia resembling those produced by several of the isolates from vetch.

MORPHOLOGICAL STUDIES.—Isolate 192, which was representative of the "straight" conidial type isolates, grew well on potato-dextrose agar at room temperatures, nearly covering the agar in a 9 cm. petri-dish in 10 days. At first, new transfers produced a sparse, white mycelial growth, but after several days the centers of the growth became black and much appressed. The diameter of the blackened areas increased with increased marginal growth of the isolate. These firm and crust-like, jet black formations were aggregations of sclerotial masses. In old cultures the sclerotial-like masses were formed deep in the agar. The mycelium at the periphery of the colonies always appeared white; older colonies consisted of a black center, which became wrinkled with age, surrounded by a band of appressed mycelium. Setae were often present within the sclerotial masses. Most of the mycelial growth was confined to the surface of the agar.

Isolate 300 was a representative culture of a number of curved conidial isolates identified as *Colletotrichum villosum*. The isolate grew slowly on all media tested, never reaching a diameter greater than 20 mm. in 10 days. After transfer to fresh plates or slants the mycelium appeared white and appressed, spreading out flat over a small surface. Within a few days the center of the growth had produced black, pigmented mycelium, likewise much appressed. The black areas increased in diameter with increase in growth of culture. Within 7 days the blackened masses in the center of the culture became raised to form a large sclerotial clump rather than remaining flattened. In older transfers the individual sclerotial masses were deep-seated in the agar. At the same time large numbers of conidial masses, gray to buff in color, were produced in the center of the cultures. The mycelium bordering the cultures was white and appressed. These cultures exhibited no reverse color.

Measurements of conidia, setae, and acervuli obtained from plant material were made (Table 1).

PHYSIOLOGICAL STUDIES.—*Growth at various temperatures.*—Growth rates of isolates 192 and 300 were compared at various temperatures. This was accomplished by 2 methods including 3 tests for each. Equal quantities of inoculum of each isolate, respectively, were placed on agar in petri plates which were maintained at controlled temperatures for 7 days and the cultures that developed were then measured. The other

[1] Accepted for publication August 18, 1952.

This paper is a condensation of a thesis submitted by the writer to the graduate faculty of Louisiana State University in 1951 in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

The author gratefully acknowledges his indebtedness to Dr. J. G. Atkins for his suggestions and assistance throughout the course of the investigations and in the preparation of the manuscript, and to Dr. E. C. Tims for photographic assistance.

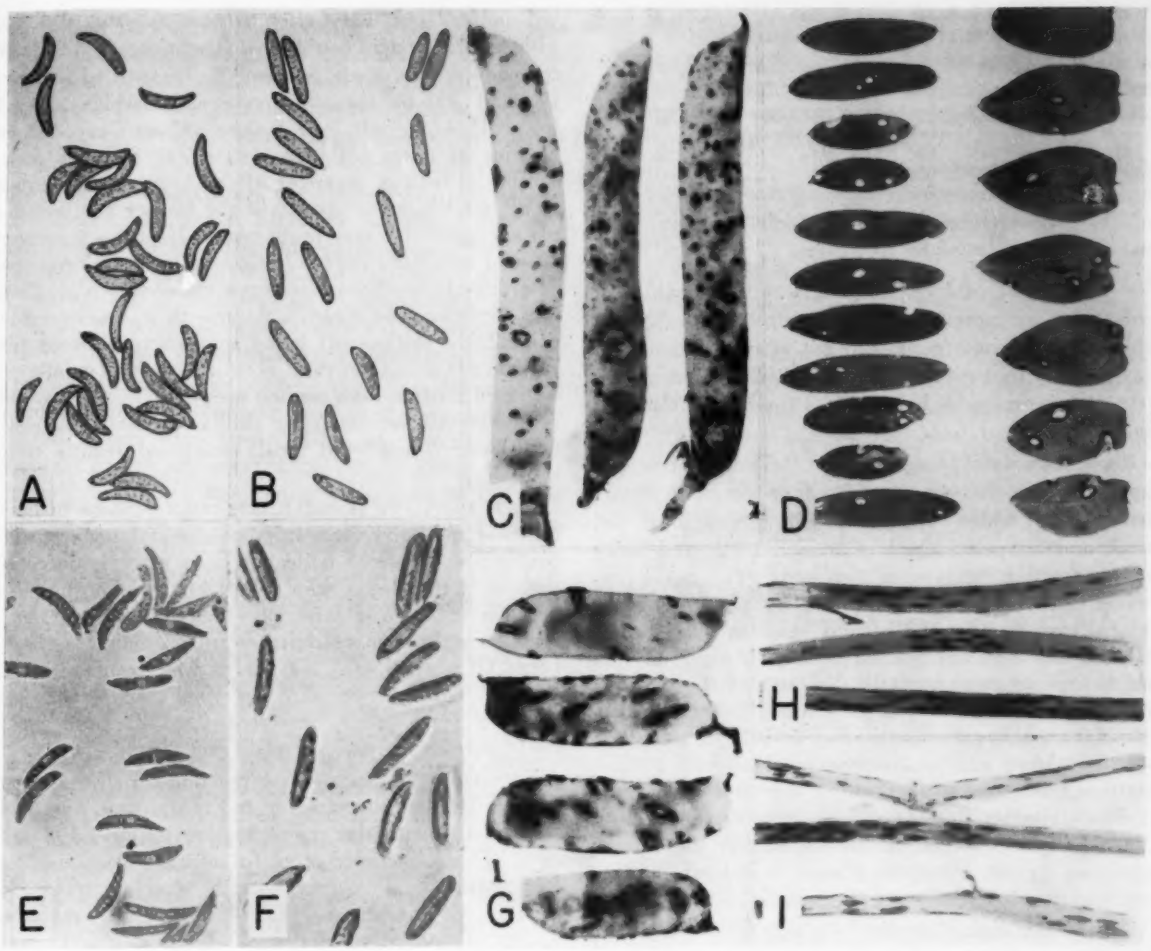


FIG. 1. Vetch anthracnose caused by Colletotrichum spp. A) Conidia of *C. villosum* traced from a photograph. B) Conidia of *C. sativum* traced from a photograph. C) Natural pod spot infection on common vetch (*Vicia sativa*). D) Natural infection on common vetch leaflets above and hairy vetch (*V. villosa*) leaflets below. E) Conidia of *C. villosum*. F) Conidia of *C. sativum*. G) Natural pod spot infection on hairy vetch. H) Natural stem spot infection on hairy vetch. I) Natural stem spot infection on common vetch.

method consisted of determining the percentage germination of conidia which were spread over the surface of agar in petri plates and maintained at controlled temperatures for 3 days. Controlled temperatures used were 7°, 15°, 18°, 22°, 25°, 27°, 33°, 36° and in some tests 40° C. When the former method was used, the optimum temperatures for growth were approximately the same (between 22° and 27° C.) for both isolates. Growth in diameter of the 192 type isolate averaged 40 mm., whereas that of the 300 type averaged 12 mm. At 33° C. or above isolate 300 failed to grow while the growth of isolate 192 was ½ that produced at optimum temperatures. Cultures of the latter type were 3 or more times the diameter of the former at 18°, 22°, 25°, and 27° C. Significantly, cultures of isolate 192 grew at temperatures above the maximum growth of isolate 300.

TABLE 1.—*Measurements in microns of conidia, setae, and acervuli of isolates 192 and 300*

		192	300
Conidia	Range	17-26 × 3.7-5.6	15-24 × 3.7-5.6
	Average	21.2 × 3.8	18.5 × 4.2
Setae	Range	60-200 × 6.5-9.3	55-178 × 6.5-9.3
	Average	126 × 7.1	110 × 7.3
Acervuli	Range	50 — 125	55 — 150
	Average	85	120

When the latter method was used the optimum temperatures for conidial germination of both isolates were approximately the same, that is, between 22° and 27° C. (Table 2). Isolate 300 had a high percentage germination at 18° C. This was in agreement with results of temperature studies in the previous tests. Conidia of isolate 192 germinated more readily at temperatures above the optimum than those of isolate 300. On the other hand, germination of isolate 300 exceeded that of isolate 192 at temperatures below the optimum.

TABLE 2.—*The percentage germination of conidia of both types of isolates at various temperatures*

Isolate No.	Temperature, °C.									
	7	15	18	22	25	27	30[a]	33	36	40[a]
192	0	0	9	84	92	93	92	82	52	6
300	21	53	89	92	94	92	92	42	0	0

[a] These temperatures used in 1 test only.

The most significant observation was that conidia of isolate 192 germinated at temperatures above 33° C., while those of isolate 300 did not. Just as important was the fact that conidia of isolate 192 did not germinate at temperatures below 18° C., whereas those of isolate 300 did.

Growth on various agar media.—Growth of isolate types 192 and 300 was compared on potato-dextrose, carrot, bean, white corn meal, yellow corn meal, oat meal, and Czapek's agars. Common vetch and hairy vetch decoction agars were also used. The usual procedure for transfer was followed by placing biscuit cuts of mycelium on the various agars in petri-dishes. All cultures were maintained at 25° C. for 7 days at which time measurements in diameter of the cultures were recorded. Isolate 192 grew much faster than isolate 300 on all agars tested. Isolate 192 grew best on potato-dextrose and white corn meal agars. Potato-dextrose and carrot agars were the best media for growth of isolate 300. The latter grew very poorly on Czapek's agar whereas on the same agar the former produced ½ the optimum growth. Conidial production was about the same on all media.

Growth on liquid media.—Growth of isolates 192 and 300 was compared in Fries liquid medium supplemented with casein and yeast extract. Loop transfers of concentrated conidial suspensions were made to 20 ml. of medium at pH 6.2 and incubated at 27° C. Five days later the fungus mats which developed were removed from 4 flasks, respectively, of each isolate, washed thoroughly with distilled water, oven dried, and weighed. This procedure was followed every 24 hours for 11 days. Isolate 192 produced considerably more growth than isolate 300. The average dry weights of isolate 192 from the fifth day to the eleventh day inclusive were 17.5 22.8, 22.7, 32.1, 49.7, 55.2 and 55.0 mg.; those of isolate 300 were 3.0, 3.5, 6.0, 9.2, 12.1, 15.8, and 15.8 mg. Two additional experiments yielded similar results.

Conidia of isolate 192 germinated within 8 hours at optimum temperatures in the supplemental Fries medium and within 15 hours in sterile distilled water. Conidia of isolate 300 germinated within 15 hours in the supplemented Fries medium and within 24 hours in sterile distilled water.

Acid tolerance.—Preliminary studies indicated that isolate 192 was relatively tolerant to acid media; that is, the fungus tolerated a concentration of 3 drops of 50 percent lactic acid in 15 ml. of medium. Weimer (9) pointed out that *Colletotrichum villosum* did not withstand such acid conditions. Therefore, in 3 tests, a comparison was made between the growth of isolates 192 and 300 on potato-dextrose agars which ranged from pH 4.8 to pH 8.6. Isolate 192 was capable of growing at lower pH than isolate 300, since no measurable growth in diameter of the latter was detected at pH 4.8 while the growth of the former at the same pH averaged 26.6 mm. in diameter. How much greater an acid condition isolate 192 could withstand was not determined. Neither isolate grew under very high alkaline condition; no measurable growth was detected at pH 8.2, the critical pH being somewhere between pH 7.6 and pH 8.2. Growth of both isolates was compared in liquid medium, the method used for inoculation and growth determination being similar to that previously described. When solid media was used results were similar.

SEED TESTS FOR POSSIBLE INFECTION.—Seeds of both common and hairy vetch from a commercial source and common vetch seeds collected from severely infected pods at Baton Rouge were tested in the laboratory for possible seed borne infection. These seeds were germinated in agar in petri-dishes and in moisture chambers. Of a total of 2,912 commercial common vetch seeds, 5,096 commercial hairy vetch seeds, and 941 common vetch seeds harvested from diseased pods, *Colletotrichum* spp. developed from none.

SPECIFIC RESISTANCE.—A large number of seed lots, many with plant introduction and forage crop numbers, were tested with the representative isolates, 192 and 300. These included the following vetch species: *Vicia sativa* L., *V. villosa* Roth, *V. dasycarpa* Ten., *V. alba* L., *V. angustifolia* (L.) Reichard, *V. pannonica* Crantz, *V. articulata* Willd., *V. benghalensis* L., and *V. grandiflora* Scop. Other species tested were *V. ludoviciana* Nutt., *V. hirsuta* (L.) S. F. Gray, and *V. aurantia* Boiss. These vetches were grown in sterilized soil in 3-in. pots in the greenhouse, and inoculated with conidial suspensions of isolates 192 and 300, respectively. The plants were placed in a moisture chamber for 72 hours and then removed to a greenhouse bench. In each inoculation series approximately 20 plants representing a given seed lot were inoculated (2 pots of each with 10 plants per pot.) Controls consisted of noninoculated plants placed in the moisture chamber with the inoculated ones. Some seed lots of vetch were tested as many as 7 times, others only once, since in some instances only a few seeds were available. However, all vetch species were tested 3 or more times.

The following vetch species were found to be resistant to isolate 192: *Vicia benghalensis, V. ludoviciana*, and *V. villosa*. The first 2 species were more resistant than the latter. *V. sativa, V. alba, V. dasycarpa, V. angustifolia, V. pannonica, V. grandiflora, V. articulata, V. hirsuta*, and *V. aurantia* were susceptible to isolate 192. When the susceptible species were inoculated with isolate 192, severe or very severe infection resulted. In all cases numerous spots developed on

stems and leaves. The spots often coalesced so that stems and petioles were girdled, causing them to become weak, bend over, and soon die. Killing of susceptible plants was aided by rapid defoliation. Infection was so severe that the most susceptible species were killed in 7 days after inoculation.

The same vetch species were also tested with isolate 300 in the greenhouse, although not all of the seed lots were included. The following species were considered to be resistant: *V. alba, V. sativa, V. aurantia, V. pannonica, V. angustifolia, V. grandiflora,* and *V. hirsuta. V. benghalensis, V. villosa, V. dasycarpa, V. ludoviciana,* and *V. articulata* were susceptible.

HOST RANGE.—Since some of the original isolates of the 192 type were obtained from field peas, and since similar plants were found to be susceptible in preliminary greenhouse inoculation tests, a group of other leguminous plants was tested with isolates 192 and 300. Included in this group were *Melilotus indica* All., soybeans (*Soja Max* Piper), golden gram (*Phaseolus aureus* Roxb.), common alfalfa (*Medicago sativa* L.), red clover (*Trifolium pratense* L.), crimson clover (*T. incarnatum* L.), white clover (*T. repens* L.), *Persian* clover (*T. resupinatrum* L.), white dutch clover (*T. repens* L.), alyce clover (*Alysicarpus vaginalis* D. C.), Sericea lespedeza (*Lespedeza Sericea* Don.), Kobe lespedeza (*L. striata* Hook and Arn.), Korean lespedeza (*L. stipulacea* Maxim), Singletary peas (*Lathyrus hirsutus* L.), sweet peas (*Lathyrus odoratus* L.), Dixie Wonder peas and Austrian Winter peas (*Pisum sativum var. arvense* L.), creole peas (*P. sativum* L.), trefoil (*Lotus uliginosus*), iron cow peas (*Vigna sinensis* Endl.), Black-eyed peas (*V. sinensis* Endl.), Valencia peanuts and Spanish Peanuts (*Arachis hypogea,* L.), *Crotalaria species* L., *C. spectabilis,* and *C. intermedia,* blue lupine (*Lupinus hirsutus* L.), white lupine (*L. albus* L.) and yellow lupine (*L. luteus* L.). Spots appeared on leaves and stems of the Dixie Wonder, Austrian Winter, Creole, Singletary, and sweet peas within 4 days after inoculation with isolate 192. Four days later the leaves of these same plants had become severely infected. Infection was not severe on the stems, but some plants were girdled and killed. However, the leaves contained many spots. Petioles of *Melilotus indica* were severely infected by isolate 192, but only a few spots were produced on the leaflets.

Similar pea plants were resistant to isolate 300. *Melilotus indica* was immune from it. Only a few spots were observed on the pea plants, and these were nearly always formed on senescent leaves. They appeared 10 to 14 days after inoculation.

TECHNICAL DESCRIPTION OF ISOLATE 192 TYPE.—*Colletotrichum sativum* sp. nov.—Maculis in siliquis, impetu in Viciae species facto, forma inter se dissimilibus sed eis in stirpibus colore similibus. Acervulis in Stirpibus 55-125 μ diametro sed haud confluentibus, eis in foliolis amphigenis vel hypophyllis. Saetis copiosis, in basi perbrunneis, se in extremis in colorem subbrunneum vel cinereum mutantibus, medio inter maximam minimamque trans bulbi basim 126 μ (60-200 μ) $\times$ 7.1 μ (6.5-9.3 μ), rotunde vel paene praeacute fastigatis, saepta 1-5 habentibus. Conidiis hyalinis, fere rectis, retuse fastigatis, unicellularibus, medio inter maximum minimumque 21.1 μ (17-26 μ) $\times$ 3.8 μ (3.7-5.6 μ) plerumque 22.2 μ $\times$ 3.7 μ.

Colletotrichum sativum n. sp.—Leaf spots typically circular to linear, sometimes irregular, light brown to gray with garnet-brown to warm sepia (7), narrow border. Stem spots similar in color, becoming dark brown to black, linear in shape. Pod spots differ in shape with vetch species attacked, but are similar in color to stem and leaf spots. On stems acervuli 55 to 125 μ in diameter and not confluent, on leaflets amphigenous or hypophyllous. Conidial masses ochraceous-buff (7) to gray. Setae when present, abundant, Brussel's brown (7) at the base becoming lighter brown to gray at the tips, average 126 μ (range 60 to 200 μ) long by 7.1 μ (range 6.5 to 9.3 μ) wide across the bulbous base, tapering to a rounded or sometimes nearly pointed tip, containing 1 to 5 septa. Conidia hyaline, nearly straight, bluntly tapered, unicellular, average 21.2 μ (range 17 to 26 μ) by 3.8 μ (range 3.7 to 5.6 μ), the most common size 22.2 μ by 3.7 μ.

Habitat: Parasitic on stems, leaves and pods of *Vicia sativa* L., *V. villosa* Roth., *V. dasycarpa* Ten., *V. alba* L., *V. angustifolia* (L.) Reichard, *V. pannonica* Crantz., *V. articulata* Willd., *V. benghalensis* L., *V. grandiflora* Scop., *V. ludoviciana* Nutt., *V. hirsuta* (L.) S. F. Gray, *V. aurantia* Boiss., *Pisum sativum* L., *Pisum sativum* var. *arvense* L., *Lathyrus hirsutus* L., and *L. odoratus* L. in Louisiana, U. S. A.

Specimens have been filed in the herbaria of the Department of Botany, Bacteriology, and Plant Pathology, Louisiana State University, Baton Rouge, La., Mycological Collections, Bureau of Plant Industry, Beltsville, Md., and Department of Plant Pathology, Cornell University, Ithaca, N. Y. Collections were made on *Vicia sativa* L., April 2, 1951, by N. L. Horn at the Agricultural Experiment Station, Louisiana State University. No. 38822 (Dept. Plant Path., Cornell University) is designated as type.

DISCUSSION.—Weiss (12) lists the following anthracnose fungi as having been reported on *Vicia* spp., excluding *V. faba,* in the United States: *Colletotrichum viciae, C. villosum, Kabatiella nigricans,* and *Gloeosporium davisii.* Of the isolations made by the author in 1949 and 1950, *C. villosum* was the only *Colletotrichum* species of this group that was isolated from diseased vetch plants in Louisiana. Isolates considered to be *K. nigricans* in a preliminary report (4) were later found to be *C. villosum.* Bain (1, 2, 3) reported *C. viciae* on vetch in Mississippi and Louisiana in 1944, but it was pointed out later (6) that the fungus observed was *C. villosum. C. viciae* was listed by Weiss (12) as occurring in Louisiana and Mississippi. The reports were probably from Bain's observations in 1944 and 1945. Therefore, it was obvious that *C. viciae* was not found in Louisiana at that time as indicated. Since the descriptions of the conidia of *C. villosum* and *C. viciae* are similar, and since no other *Colletotrichum*

species on vetch had been described at the time of Bain's surveys, the confusion is understandable.

C. villosum was described by Weimer (9) in 1945. He pointed out that hairy vetch was susceptible to this fungus whereas most selections of common vetch were resistant. A previous survey (8) indicated similar observations on field-grown plants. Reports by the Georgia Experiment Station (10, 11) for the following 3 years indicated that common vetch plants were severely infected with anthracnose. The implication was that the same fungus was involved. Since common vetch was resistant to *C. villosum* in the present studies and in Weimer's inoculation tests, it seems probable that another *Colletotrichum* species was responsible for the sudden susceptibility of common vetch to anthracnose. It seems possible that the "straight" conidial type became established in the Georgia Experiment Station area later than 1945, after *Colletotrichum villosum* had been described, and was responsible for this change. Since the symptoms caused by both organisms are similar, field observations alone would not have indicated that 2 species were involved in the disease complex.

No experimental evidence was obtained as to how the "straight" conidial type became established in Louisiana. Possibly the fungus was introduced by infected seeds, but certain evidences do not support this possibility. A large number of commercially grown seeds of common and hairy vetch were germinated in moisture chambers and in agar in the laboratory. Common vetch seeds obtained from severely infected pods were also germinated on agar. No *Colletotrichum* spp. were observed on the developing seedlings. Weimer (9) mentioned that the use of clean, disease-free seed is a possible means of control for *C. villosum*. But he gave no experimental evidence that vetch seeds carry the fungus. Diseased plant material stored in wire baskets outside the greenhouse over the summer was also placed in moisture chambers in the laboratory. No anthracnose fungi were observed to develop from this plant material. Because field peas were susceptible to the "straight" conidial type, and because mixtures of field peas and vetch were frequently used as a winter cover crop on farms visited in Louisiana, the disease problem becomes more complicated. Native vetch species also were found to be susceptible to the "straight" conidial type.

The studies concerning *C. villosum* confirm those in Weimer's paper (9) except for the susceptibility of *V. articulata* (*V. monantha*) which he had listed as resistant to *C. villosum*.

SUMMARY

Two different anthracnose fungi were found associated with diseased vetch plants in Louisiana.

Fungi pathogenic to vetch species were *C. villosum* and *C. sativum* n. sp. A technical description of the latter is given.

A detailed study was made of *C. villosum* (isolate 300 type) and *C. sativum* (isolate 192 type). They were found to differ in morphological, physiological, and cultural characteristics and in pathogenicity.

Vicia benghalensis, *V. ludoviciana*, and *V. villosa* were resistant to *C. sativum*; *V. sativa*, *V. dasycarpa*, *V. angustifolia*, *V. pannonica*, *V. grandiflora*, *V. articulata*, *V. hirsuta*, *V. alba*, and *V. aurantia* were susceptible. *V. alba*, *V. sativa*, *V. angustifolia*, *V. pannonica*, *V. grandiflora*, *V. aurantia*, and *V. hirsuta* were resistant to *V. villosum*. *V. benghalensis*, *V. villosa*, *V. dasycarpa*, *V. ludoviciana*, and *V. articulata* were susceptible.

Austrian Winter, Dixie Wonder, Creole, sweet, and Singletary peas were susceptible to *C. sativum*. Similar plants were resistant to *C. villosum*. The former but not the latter attacked *Melilotus indica*.

Neither *C. villosum* nor *C. sativum* were found to be seed borne under conditions described.

Department of Botany, Bacteriology and Plant Pathology
Louisiana State University
Baton Rouge, Louisiana

LITERATURE CITED

1. Bain, D. C. 1944. Disease of vetch in Mississippi. U.S. Dept. Agr. Pl. Dis. Rptr. **28**: 293.
2. Bain, D. C. 1944. Diseases of various legumes in Mississippi. U.S. Dept. Agr. Pl. Dis. Rptr. **28**: 160.
3. Bain, D. C. 1944. Diseases of vetch. U.S. Dept. Agr. Pl. Dis. Rptr. **28**: 189.
4. Horn, N. L. and J. G. Atkins. 1950. Pea and vetch diseases in Louisiana. Phytopathology **40**: 788.
5. Horn, N. L. and J. G. Atkins. 1951. A new anthracnose of vetch. Phytopathology **41**: 18.
6. Person, L. H. 1944. List of plant diseases observed during surveys in Mississippi and Louisiana, August to November, 1943. U.S. Dept. Agr. Pl. Dis. Rptr. Suppl. **148**: 282.
7. Ridgway, R. 1912. Color standards and color nomenclature. 43 pp., 53 color plates. (Washington).
8. Weimer, J. L. 1942. Diseases of soybeans, Austrian Winter peas, vetchs, and other forage legumes. Fifty-forth Ann. Rpt. Ga. Exp. Sta. July 1941-1942. P.75.
9. Weimer, J. L. 1945. A new species of Colletotrichum on vetch. Phytopathology **35**: 977-990.
10. Weimer, J. L. 1946. Diseases of field peas, vetches, soybeans, and other forage legumes. Fifty-eighth Ann. Rpt. Ga. Exp. Sta. July 1945-1946. pp. 74-77.
11. Weimer, J. L. 1946. Diseases of soybeans, Austrian Winter peas, vetches, and other forage legumes. Fifty-ninth Ann. Rpt. Ga. Exp. Sta. July 1946-1947. pp. 83-85.
12. Weiss, F. 1946. Check list revision. U.S. Dept. Agr. Pl. Dis. Rptr. **30**: 218-219.

OBSERVATIONS ON CRAZY TOP OF CORN [1]

Arnold J. Ullstrup

Crazy top of corn is widespread over most of the central Corn Belt (4, 5, 6, 17). Although the disease is sporadic in occurrence, and total losses are negligible, yield reduction in individual fields may sometimes exceed 50 per cent. The cause of the disease has not been fully understood, although its resemblance to infectious diseases caused by species of *Sorosporium* and *Sclerospora* has been recognized (5, 6, 17).

Numerous cases of crazy top have been seen in Indiana and adjoining states during the past several years. The disease was unusually prevalent in Indiana in 1949. In one instance about 75 per cent of the plants in a 7 acre portion of a field were affected. This field, near Lafayette, was first observed in mid-July and the development of the disease was watched as the season progressed. The observations reported in this paper were made over a period of several years and are presented as suggestive evidence that crazy top of corn is an infectious disease caused by *Sclerospora macrospora* Sacc.

Symptoms.—A number of distinct symptoms constitute the crazy top syndrome. Single plants may show 1 or more symptoms.

Proliferation of the tassel, from which the name crazy top is aptly derived (Fig. 1,B,E), is the most conspicuous symptom. This witches' broom condition, which may partly or completely involve the tassel, is due to the replacement of normal structures by small leaves. As many as 12 well developed ear shoots have been observed distributed along the stalks of affected plants. Excessive numbers of nodes above the lowest ear and in the ear shank is also a frequent symptom. Occasionally ear shanks are branched. Leaves of affected plants are only ⅓ the width of normal leaves. Such strap-like leaves have a leathery texture (Fig. 1,F), the lower epidermis may be slightly roughened, and longitudinal, translucent streaks of light and normal green color are evident in the blade.

The sheaths of strap-like leaves often show a warty surface (Fig. 1,H). Stunting is a symptom of severely affected plants (Fig. 1,A). Such plants may attain a height of only 2 to 3 ft. when normal plants are 7 to 9 ft. high. Tillering is often associated with stunting, and as many as 12 tillers have been seen on a single plant (Fig. 1,C). Barrenness is a common symptom and well over 95 per cent of affected plants produce no ears. Mildly affected plants showing part or complete proliferation of the tassel may occasionally produce a normal ear. Severely affected plants will, in rare instances, produce nubbin ears with a few kernels. Roots of stunted and tillered plants are poorly developed and the plants can be easily pulled from the soil.

Intergradations are present, but the association of definite symptoms in individual plants is striking: (a) severely stunted plants usually show excessive tillering, bear leathery strap-like leaves, leaf sheaths are warty, and tassels and ears often fail to develop (Fig. 1,C,D); (b) moderately stunted plants show less tillering, leaves are less reduced in width, but often striate (Fig. 1,G), tassels are proliferated, and ear shoots excessive; (c) plants of normal height usually show tassel proliferation, excessive numbers of ear shoots and nodes, but leaves and leaf sheaths are normal.

Symptoms of crazy top appear to be different from those of downy mildew of corn caused by *Sclerospora graminicola* (Sacc.) Schroet. The narrow, leathery leaves and wartiness of leaf sheaths, found in plants severely affected with crazy top, have not been described as symptoms of downy mildew. Irregular, grayish blotching and mottling of leaves is a common symptom of downy mildew (11, 12), but has not been observed on plants affected with crazy top.

Plants of crabgrass, *Digitaria sanguinalis* (L.) Scop., witchgrass, *Panicum capillare* (L.), and green foxtail, *Setaria viridis* (L.) Beauv. with typical crazy top symptoms have been found growing near affected corn plants. Koehler (6) recorded crazy top on green foxtail and barnyard grass, *Echinochloa crusgalli* (L.) Beauv.

Factors affecting the occurrence of crazy top.—Flooding or water-logging of the soil has been associated with every case of crazy top observed. Affected areas were generally low spots in the fields, but occasionally the difference in elevation was hardly perceptible. In fields that had been flooded between planting time and when plants were 3 to 4 in. high crazy top occurred, but not when flooded after corn was 1 ft. or more in height. The duration of flooding has not been critically studied, but in 1 field where the disease was severe, water stood on 3 to 4 in. seedlings for 24 hours. These observations suggest that flooding or water logging, between planting and the time seedlings are 3 to 4 in. high are contributory factors in initiating infection.

Histological observations.—Sections were made from fresh tissues and from fixed, paraffin embedded material. Detection of mycelium in fresh sections was greatly facilitated by staining with zinc chloriodide. Mycelium of the parasite stained deep bluish purple while host tissue remained nearly colorless. The stain faded after 1 to 2 hours and could not be effectively used on fixed sections.

Mycelium was found in brace roots, stalk tissue, leaves and floral structures of affected plants. A

[1] Accepted for publication September 13, 1952.

Contribution from the Division of Cereal Crops and Diseases, B.P.I.S.A.E., A.R.A., U.S.D.A., and the Department of Botany and Plant Pathology, Purdue University Agricultural Experiment Station, Lafayette, Indiana. Journal Paper No. 616 of the Purdue University Agricultural Experiment Station.

FIG. 1. Symptoms of crazy top of corn. A) Sweet corn plant showing stunting. B) Variation in extent and type of tassel proliferation. C) Severe infection of dent corn plant, showing stunting (plants were 3 feet high, healthy plants were 7 to 9 feet high), tillering, narrow, leathery leaves, and absence of inflorescence. D) Terminus of severely affected plant. E) Typical witches' broom tassel. F) Narrow, leathery, strap-like leaf with longitudinal striations. G) Light and dark green streaking in leaf of nearly normal width. H) Wartiness of leaf sheath due to development of oogonia within the tissue.

limited number of sections from roots were examined, but in none of these was there evidence of the fungus. The mycelium and the oogonia were especially abundant in the severely stunted plants. Few such plants produce ears, but some were collected and sections made of the cobs and kernels. Mycelium was present in the cob tissue and in some instances in the scutellum. (Fig. 2,I) and coleorhiza. The mycelium was sparse and oogonia very few in number in plants of noraml height showing only proliferated tassels. It was often necessary to examine a great many sections from such plants before any evidence of the fungus was found.

Mycelium was intercellular and coenocytic, and varied considerably in diameter, (Fig. 2,D) depending apparently, on the size of intercellular spaces. No haustoria were observed and no necrosis of host cells was apparent.

Sporangiophores and sporangia were not observed. What appeared to be abortive sporangiophores, seen in cross-sections through leaf whorls, appeared as short hyphae, often flexous, and sometimes branched, that protruded from the stomata (Fig. 2,E,F,G). Foot-like structures of branched hyphae were present at the base of these short hyphae (Fig. 2,C). Magnus (10) observed similar structures in *Sclerospora kriegeriana* Mag.

Oogonia and oospores were found most abundantly in the strap-like leaves and the warty leaf sheaths of stunted plants. They were situated close to the vascular bundles, often in "nests" of several spores. Nests of oospores were sometimes invested in a reticulum of fibrous material that appeared to be of host origin (Fig. 2, B). Oogonia were spherical in shape in fresh host material, but where large numbers occurred together most of them were oval, possibly due to compression. Oogonia ranged from 50μ to 83μ in diameter with an average of about 65μ. Oogonial walls were about 4.5μ thick. Oospores were yellowish and ranged from 42μ to 75μ in diameter with an average of 58μ. The contents of the oospores were densely granular and contained several nuclei. Oogonial formation appeared to be preceded by a rounding-up and thickening of the mycelium into a tortuous mass (Fig. 2,A). Oogonial walls were laid down within the gnarled aggregation of mycelium.

Antheridia were observed tightly appressed to the oogonia (Fig. 2,H), and in some instances projection of a female gametangium into the antheridium was evident. Only 1 antheridium appeared to be associated with each oogonium.

A comparison of the fungus found in crazy top plants with *Sclerospora graminicola* reveals differences between the 2 organisms: oospores of the fungus observed in tissues of corn plants affected with crazy top were relatively large (42μ–75μ) and yellowish, corresponding to the oospores of *Sclerospora macrospora*. The oospores of *S. graminicola* are smaller (30μ–60μ) and reddish brown. Oospores were abundant in plants showing severe symptoms of crazy top. Melhus and Van Haltern (11) did not find oospores in corn plants infected with *S. graminicola*. Sporangia were not found in plants affected with crazy top. Melhus, Van Haltern and Bliss (12) demonstrated the production of sporangia on leaves of young corn plants infected with *S. graminicola*. The nuclear condition of the oospores is another distinguishing feature between the 2 fungi. The present study was not concerned with the cytological aspects of the fungus, but examination of sectioned tissues bearing oospores suggested a multinucleate condition and thus similar to *S. macrospora* (8). Oospores of *S. graminicola* are uninucleate (7).

Seed transmission of crazy top.—In 1949 nubbins bearing less than 50 kernels were harvested from severely affected plants. Fresh sections of a few kernels from each ear showed the presence of mycelium in the coleorhiza and scutellum. The mycelium was similar in appearance to that found in other tissues of affected plants, being coenocytic and staining heavily with zinc chloriodide. Remnants of the seed lots, in which infection was found, were dried and planted in steamed compost soil. Seed harvested from normal plants in the same field was planted as a control. A few plants grown from the seed from infected ears showed narrow leathery striate leaves within 6 to 8 weeks after planting. The presence of the fungus in these plants was confirmed by microscopic examination of fresh sections. Flooding of the soil was unnecessary since infection was already established, as indicated by microscopic observations on a random sample of the seed.

Results indicate that seed transmission of crazy top is possible. From a practical standpoint it is unlikely that infected seed is a means of disseminating the disease. The very few infected plants that produce ears and the small size of such ears, which would be discarded in processing, virtually precludes distribution of the pathogen in commercial seed corn.

Observations on sporangia production.—Severely infected plants were transplanted from the field to large pails provided with drainage, watered thoroughly, and brought to the greenhouse. The plants were sprayed with distilled water and held in a rain chamber in the dark for 4 days. The temperature was varied between 18°C and 30°C. Leaves were examined at 24 hour intervals but no sporangia were produced. Diseased plants grown from infected seed were held in moist chambers with moistened slides attached beneath the leaves. Examinations of the slides and leaves were made at 12 hour intervals over a 48 hour period but no sporangia were found. In September, 1951, diseased plants of corn, crabgrass, witchgrass, and green foxtail were transplanted from the field, placed in moist chambers, and sprayed with distilled water. Scrapings of leaves were examined between 1:00 a.m. and 4:00 a.m. on 3 successive mornings, but no sporangia were detected.

Observations on oospore germination.—Mature leaves and leaf sheaths containing an abundance of

oospores were broken into fine particles. One lot of fragmented tissue was submerged in distilled water and held at 18°, 24°, and 30°C for 4 days. A second lot of the material was alternately frozen and thawed at 12 hour intervals over a period of 1 week. A third lot of the material was placed on wet filter paper and held for 3 days in an atmosphere of low oxygen tension. Frequent examination was made of the different treatment lots, but there was no indication of oospore germination.

INFECTION EXPERIMENTS.—In the fall of 1949 soil collected beneath infected plants was placed in glazed pots and planted with corn, wheat, oats, barley, green foxtail, and barnyard grass. When seedlings began to emerge, drainage holes were stoppered and the pots flooded for 24 hours. No symptoms of crazy top became evident in any of the species during the 8-week period under observation. The experiment was repeated in the spring of 1950 using soil from the same origin, but which had over-wintered outside. Results were again negative.

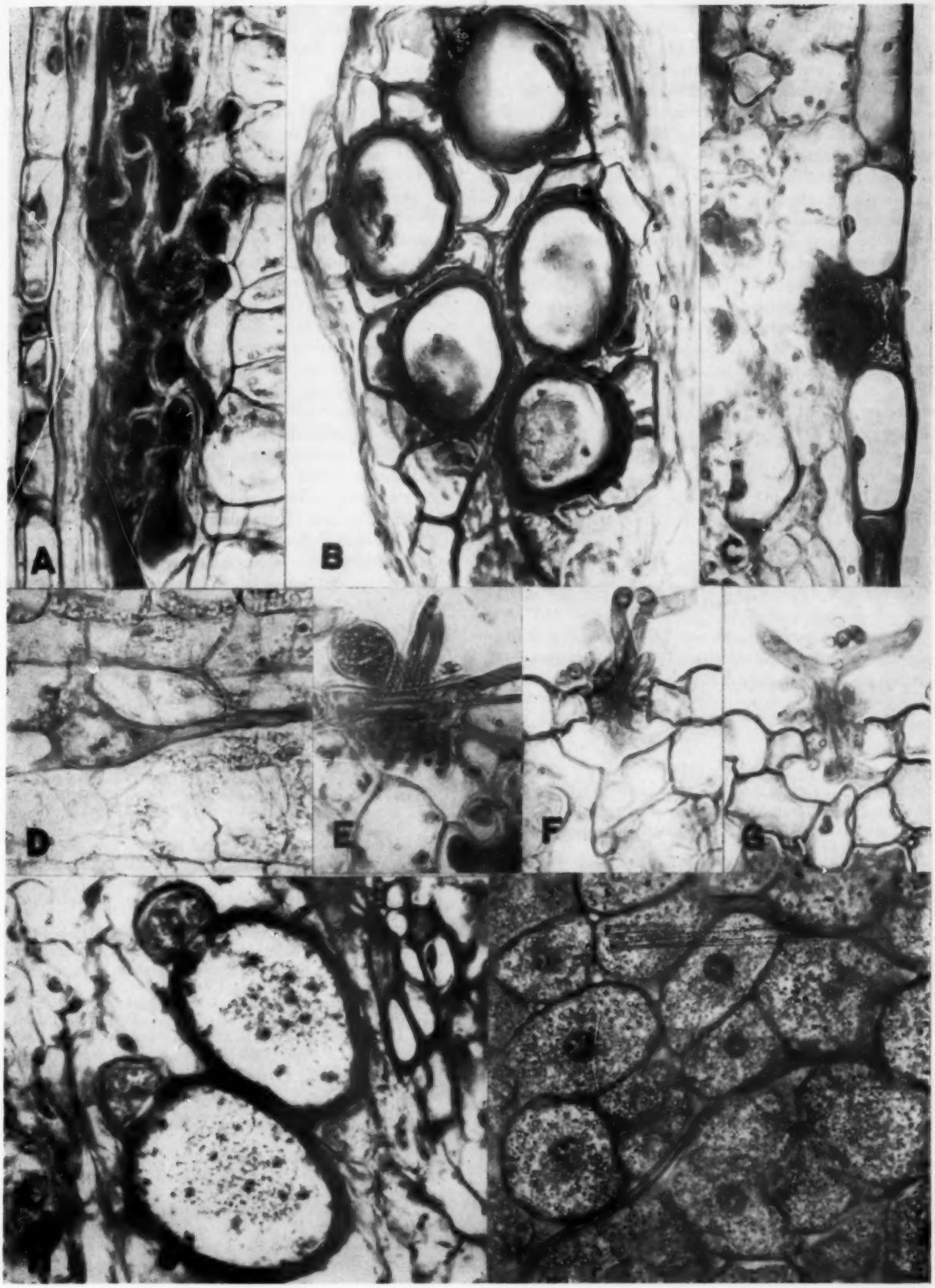
Mature leaves containing an abundance of oospores were dried, ground into coarse fragments and placed on soil in glazed pots. Corn was planted in the material and covered with soil. When seedlings were 1 in. high the pots were stoppered and flooded for 24 hours. Crazy top failed to develop during a 2-month period following flooding. In 1950 a sample of soil taken from an area in a field where the disease occurred was used in an attempt to induce infection. Corn was planted in the soil and flooded for 24 hours and 48 hours 2 days after planting, when seedlings were emerging, and when seedlings were 3 to 4 in. high. No symptoms became evident during the following 2 months. The experiment was repeated in 1951 using soil of different origin, but no symptoms developed. Seedlings 3 to 4 inches high were immersed for 24 and 48 hour periods at 10°, 17°, and 24°C in an aqueous suspension of soil collected beneath crazy top plants. Crazy top failed to develop on any of the plants.

DISCUSSION.—*Sclerospora macrospora Sacc.* was first described on *Alopecurus* sp. collected in Australia by Tepper (16). No asexual stage was described. In the United States *S. macrospora* has been found on wheat (19), barley (9), and oats (13). No asexual stage of the fungus has been found on these hosts. Peyronel (15) observed lemon-shaped zoosporangia emerging from the stomata of leaves and stems of wheat infected with *S. macrospora*. The zoosporangia developed after the host material had been submerged in distilled water. Peglion (14) found lemon-shaped conidia measuring 60μ–70μ × 38μ–52μ attached to short conidiophores arising from the stomata of infected *Holcus lunatus* L. It was pointed out that these structures resemble sporangiophores of the genus *Phytophthora* rather than the branched sporangiophores of species of *Sclerospora* in which an asexual form is known. Peglion did not describe the mode of germination of the sporangia. Peglion (14) described also the germination of oospores in fragmented tissues of *H. lunatus*. The wall of the oospore split and a thin-walled tube emerged, on the apex of which was borne a lemon-shaped conidium measuring 70μ–80μ × 55μ–60μ. He believed the conidium to be a zoosporangium since zoospores were found in the surrounding water in which the host material was immersed. Tanaka (18) found conidia measuring 46μ × 74μ emerging from stomata of wheat infected with downy mildew. Because the morphology of these conidia was strikingly different from those of other members of the genus in which an asexual stage is known, Tanaka transferred the fungus causing downy mildew of wheat in Japan from the genus *Sclerospora* to *Phytophthora*. In McDonough's (8) cytological study of the fungus causing downy mildew of wheat in the United States he pointed out that the organism does not fit well in the genus *Sclerospora*. The bases for this stand are: (a) the multinucleate condition of mature oospores in contrast to the monocaryotic nature of oospores of other species of the genus, and (b) the occurrence of sporangia as reported by Peyronel (15), Peglion (14) and Tanaka (18), that are strikingly different from other species of the genus *Sclerospora*. McDonough (8) does not agree with Tanaka's transfer of the fungus to the genus *Phytophthora* because of the thick oospore wall of the downy mildew organism which is not characteristic of *Phytophthora*.

Although the present taxonomic position of *S. macrospora* is uncertain, it appears advisable to consider the organism as the cause of crazy top of corn. This position is based on the following reasons: (a) the organism has been found consistently associated with plants showing symptoms of the disease and has not been encountered in apparently healthy, symptomless plants; (b) the size, shape and color of the oospores coincide with those characters of *S. macrospora* as originally described. The apparent absence of an asexual stage in the fungus found associated with crazy top lends some support to the contention that *S. macrospora* is involved. Further supporting evidence is found in the striking similarity between crazy top of corn in the United States and a disease of corn, caused by *S. macrospora*, reported in Italy (1, 2, 3). The symptoms of the disease, morphology of the causal organism, and the pathological histology described and illustrated by the Italian workers correspond very closely to the observations reported in this paper. The disease in Italy occurred following flooding of the soil as does crazy top. Evidently the Italian papers have

→

FIG. 2. Photomicrographs of *Sclerospora macrospora* within host tissue. A) Aggregation of mycelium previous to oospore formation. B) Nest of oospores in leaf of witchgrass showing fibrous reticulum. C) Foot like structure in sub-stomatal chamber. D) Mycelium in pith showing variation in diameter. E, F, G) Hyphae (abortive sporangiophores) protruding from stomata. H) Oogonia and antheridia. I) Mycelium in scutellum.


A
B
C
D
E
F
G

been overlooked by those who have observed crazy top of corn in the United States; otherwise the similarity between symptoms of crazy top and the disease in Italy would have been recognized.

From the standpoint of pathology the evidence presented in this paper that *S. macrospora* is the inciting agent of crazy top is entirely circumstantial. It has not been possible, to date, to transfer the disease from infected to healthy plants or to establish the disease in plants by growing them in presumably contaminated soil. Although the evidence is circumstantial it should be pointed out that in downy mildew of wheat, barley, oats, and in the disease of corn in Italy cited above, *S. macrospora* is incriminated on similar evidence without positive inoculation experiments.

The failure of inoculation experiments reported here may be due to a long maturation period required by oospores in the soil. Plants grown in soil containing debris of diseased plants from the current year may not be infected if a long maturation period for oospores is necessary. It is conceivable also that the majority of oospores in the soil may germinate over a short period of time under favorable environmental conditions. If susceptible hosts are present they become infected and the soil is then virtually depleted of inoculum until debris from the diseased plants is reincorporated within the soil at the end of the growing season.

SUMMARY

The symptoms of crazy top of corn are described and illustrated. Two additional hosts, crabgrass and witchgrass, are reported. The apparent correlation between severity of symptoms and abundance of the pathogen in host tissues is pointed out. Field observations suggest that flooding of the soil at a period between planting and the 3 to 4 leaf stage is necessary for infection.

Mycelium was found in all above-ground parts of affected plants. The mycelium was coenocytic, intercellular and, in fresh tissue, selectively stained by means of zinc chloriodide. Haustoria were not found and necrosis of host cells was not evident. True sporangiophores or sporangia were not seen. Short hyphae, suggestive of abortive sporangiophores, were observed protruding from stomata. Oogonia and oospores, which were abundant in severely affected plants, were similar in size, shape, and color to the corresponding organs of *Sclerospora macrospora*. Antheridia were closely appressed to oogonia and occasionaly a female gametangium extended into an antheridium. Only 1 antheridium was associated with an oogonium.

Seed transmission of the disease was demonstrated, but seed infection is probably of little practical consequence in disseminating the disease through commercial seed channels.

Attempts to induce production of sporangia on infected plants, and to stimulate germination of oospores were negative. Infection of known suscepts could not be established under the conditions of the experiments.

The taxonomic status of *Sclerospora macrospora* and the reasons for naming the fungus as the inciting agent of crazy top of corn are briefly discussed.

PURDUE AGRICULTURAL EXPERIMENT STATION
LAFAYETTE, INDIANA

LITERATURE CITED

1. CUGINI, G. AND G. B. TRAVERSO. 1902. La Sclerospora macrospora Sacc. parassita della Zea Mays L. Staz. Sper. Agr. Ital. **35**: 46-49.
2. GABBOTO, L. 1918. La peronospora del mais. Cultivatore **64**: 331-333.
3. IPPOLITO, G. AND G. B. TRAVERSO. 1903. La Sclerospora macrospora Sacc. parassita delle inflorescenze virescenti di Zea Mays L. Staz. Sper. Agr. Ital. **36**: 975-995.
4. JOSEPHSON, L. M. AND E. M. JOHNSON. 1947. Crazy top of corn in Kentucky. U. S. Dept. Agr. Plant Disease Reporter **31**: 69-70.
5. KOEHLER, B. AND J. R. HOLBERT. 1930. Corn diseases in Illinois, their extent, nature and control. Illinois Agr. Expt. Sta. Bul. 354.
6. KOEHLER, B. 1939. Crazy top of corn. Phytopathology **29**: 817-820.
7. MCDONOUGH, E. S. 1937. The nuclear history of Sclerospora graminicola. Mycologia **29**: 151-173.
8. MCDONOUGH, E. S. 1946. A cytological study of the development of the oospore of Sclerospora macrospora Sacc. Trans. Wis. Acad. Sci. Arts, and Letters **38**: 211-218.
9. MACKIE, W. W. 1930. Sclerospora macrospora in barley. Phytopathology **20**: 107.
10. MAGNUS, P. 1895. Ueber das mycel und der parasitismus einer neuen Sclerospora Art. Bot. Centralbl. **64**: 111.
11. MELHUS, I. E. AND F. VAN HALTERN. 1925. Sclerospora on corn in America. Phytopathology **15**: 720-721.
12. MELHUS, I. E., F. H. VAN HALTERN, AND DONALD E. BLISS. 1928. A study of Sclerospora graminicola (Sacc.) Schroet. on Setaria viridis (L.) Beauv. and Zea Mays L. Iowa Agr. Exp. Res. Bul. 111, 297-338.
13. MILES, L. E. AND J. M. EPPS. 1942. The downy mildew disease of oats caused by Sclerospora macrospora. Phytopathology **32**: 867-878.
14. PEGLION, V. 1930, 1931. La formazione dei conidi e la germinazione della oospore della Sclerospora macrospora Sacc. Boll. R. Staz. Patol. Veg. Roma (N.S.) **10**: 153-164. R.A.M. **10**: 174.
15. PEYRONEL, B. 1929, 1930. Gli zoosporangi nella Sclerospora macrospora. Boll. R. Staz. Patol. Veg. Roma (N.S.) **9**: 353-357. R.A.M. **9**: 513.
16. SACCARDO, P. A. 1899. Fungi aliquot australienses. Hedwigia **29**: 154.
17. SEMENIUK, G., I. E. MELHUS, J. R. WALLIN, C. L. GILLY, AND MURIEL O'BRIEN. 1946. A dwarfing and witches' broom on corn in Iowa. (Abs.) Phytopathology **36**: 410.
18. TANAKA, I. 1940, 1941. Phytophthora macrospora (Saac.) S. Ito et I. Tanaka on wheat plant. Ann. Phytopath. Soc. Japan X: 127-138, 1940 (Japanese with English summary) R.A.M. **20**: 457.
19. WESTON, WM. H., JR. 1921. The occurrence of wheat downy mildew in the United States. U.S.D.A. Dept. Circ. 186, 6p.

OBSERVATIONS ON THE PRODUCTION OF MYCELIAL MATS OF THE OAK WILT FUNGUS IN PENNSYLVANIA [1]

C. L. Morris and C. L. Fergus [2]

The initial discovery of the mycelial mats of the oak wilt fungus in nature was made in Illinois in 1951 by Curl *et al.*[3] Since that time the discovery has been reported of similar mats and perithecia on trees killed by the oak wilt fungus in West Virginia and in Illinois.[4]

In Pennsylvania a close examination was made during the spring of 1952 of 5 separate infection areas, each at least 4 years old and containing a number of wilt-killed trees. In each of these areas, fresh mycelial mats of *Chalara quercina* were noted on at least 1 tree. The mats were similar in appearance to those described by Barnett *et al.*[5] All mats except those recently deteriorated were characterized by the abundant production of endoconidia and it was possible in most instances to secure pure cultures of the fungus by direct transfer from the sporulating mats. However, several other fungi, including *Graphium rigidum* (Pers.) Sacc. and *Endoconidophora moniliformis* (Hedgc.) Davidson, as well as *C. quercina* were also isolated.

Fertile perithecia were found on only 1 tree of the many examined. Only 2 mats of the 12 on this tree were producing ascospores. The others had deteriorated so that it was impossible to determine whether or not they had produced fertile perithecia. Microscopic examination of these mats showed typical perithecia and ascospores of the oak wilt fungus. Mycelium developed from ascospores in dilution and streak plates produced the typical endoconidia of *C. quercina*. The perithecia were not produced on the raised center portion, but only on the outer edges of the mycelial mat. (Fig. 1). This agrees with the observations of Staley and True.[4]

None of the isolates from mycelial mats produced perithecia when grown on chestnut agar. Conidial mats spermatized with endoconidia from other mats produced on the same tree also failed to produce perithecia. These facts, substantiated by laboratory examination of a number of fresh mats, indicate that the production of perithecia is not necessarily coexistent with the formation of mycelial mats under the bark of diseased trees.

Infected trees showing wilt symptoms in the summer and fall of 1951 were the only trees on which mycelial mats formed in 1952. One tree on which numerous mats were produced was sprouting along the bole. No mats were produced on the companion sprout of this tree, which wilted at approximately the same time and was felled in August 1951 at the first sign of wilting. Since every other tree in this particular area that had wilted in 1951 produced mycelial mats, the absence of mats on the felled sprout would indicate the importance of moisture in mat formation.

The first mycelial mats were noted in early March 1952. These mats apparently had developed during late winter and at the time of examination were producing numerous conidia. The same mats were still viable a month later. The longevity of mats formed in April or thereafter was considerably reduced by the adults and larvae of fungus-eating beetles and possibly the hot, dry weather. The fertile perithecia which were formed on only 1 tree were producing ascospores on May 15, 1952. By May 20 all other mats on this tree were almost completely consumed by insects. However, the 2 perithecial mats collected May 15 continued to produce new perithecia and ascospores as late as July 10, 1952 when kept at 8° C. in a moist chamber.

As many as 75 mats were produced under the bark of a single tree. Mats were found mainly on the bole but also on limbs, sometimes on limbs as small as 1½ in. in diameter.

Bark cracks, possibly caused by the pressure of growing mats, were found on many trees. However, several trees examined exhibited abundant but small sized mats under a tight bark.

On one area examined, all 4 trees exhibiting fungus mats showed the results of successful efforts of rodents, probably grey squirrels, to feed upon the mycelial mats. On 2 trees, the overlying bark had been gnawed away from at least half the mats and the thick center portion entirely consumed.

Since no fresh mats of the oak wilt fungus were found on trees dead for longer than 1 year, it would appear that they are less hazardous as a source of spores for further spread of the disease than trees more recently killed.

The discovery of mycelial mats and fertile perithecia in Pennsylvania, as well as Illinois and West Virginia indicates that their occurrence in nature is more frequent than was previously realized. The endoconidia formed on the mats could serve as sources of

[1] Accepted for publication September 28, 1952. Contribution No. 168 from the Dept. of Botany, Pennsylvania State College.

[2] Respectively, Pathologist, Division of Research, Department of Forests and Waters, Harrisburg, Pennsylvania, and Assistant Professor of Botany, Pennsylvania State College, State College, Pennsylvania.

[3] Curl, E. A., G. J. Stessel and B. M. Zuckerman. 1952. Macroscopic growth of the oak wilt fungus in nature. (Abs.) Phytopathology 42: 6.

[4] Staley, J. M. and R. P. True. 1952. The formation of perithecia of *Chalara quercina* in nature in West Virginia. Phytopathology **42**: 691-693.

[5] Barnett, H. L., J. M. Staley and R. P. True. 1952. Mycelial mats of *Chalara quercina* on killed oak trees as a potential source of perithecia in nature. Phytopathology 42: 531-532.

FIG. 1. A portion of a mycelial mat growing on the bole wood of a partially dead red oak. Numerous perithecia and exuded ascospores are being produced. Photograph by the Department of Forests and waters.

inoculum as well as the source for spermatization of other mats.

The potential importance of ascospores in above-ground spread has been postulated by Hepting *et al.*[6] and, more recently, Bretz[7] has successfully used ascospores to induce the disease by artificial inoculation. Thus, ascospore production would greatly increase the amount of inoculum in an area, and might well serve in the long distance spread by the as yet unknown vector.

[6] Hepting, G. H., E. R. Toole, and J. S. Boyce, Jr. 1951. Perithecia produced in an unpaired isolate of *Chalara quercina* and its possible significance in oak wilt control. U. S. Dept. Agr. Pl. Dis. Rptr. 35: 555.

[7] Bretz, T. W. 1952. The perithecial stage of *Chalara quercina* Henry. (Abs.) Phytopathology 42: 3.

DEPARTMENT OF BOTANY
THE PENNSYLVANIA STATE COLLEGE
STATE COLLEGE, PENNSYLVANIA

LEAF FLECK, AN APHID BORNE PERSISTENT VIRUS DISEASE OF MAIZE [1]

Warren N. Stoner [2]

In the early summer of 1946, a spotting of the leaves of corn, *Zea mays* L., was noted to be spreading in a small planting of the variety Golden Bantam at San Pablo, California. Plants with the same symptoms were found in all fields of this general locality. Microscopic examination revealed no evidence of the presence of fungi or bacteria.

The apple grain aphid, *Rhopalosiphum prunifoliae* (Fitch),[3] was present in these fields in very large numbers. Sweeping and close examination of the plants revealed the presence of no other aphid species. Populations of this aphid were taken from plants showing the spotting and transferred to healthy corn seedlings. After 6 weeks similar spots began to develop in these plants, indicating that transmission of a virus had been effected.

REVIEW OF LITERATURE.—Only 3 virus diseases of corn have been reported in the continental United States: sugar cane mosaic, southern celery mosaic (cucumber virus 1), and corn stunt.

Brandes (4) described under the name corn mosaic, a virus disease which occurred in corn and sorghum in Puerto Rico and the southern United States. He reported transmission of the virus by *Rhopalosiphum maidis* (Fitch) (*Aphis*). In a previous study (3) he indicated the possibility of the virus being spread by aphids from sugar cane to sugar cane. In a later report by Brandes and Klaphaak (5) this disease of corn was shown to be caused by the sugar cane mosaic virus.

In 1922 Kunkel (10) investigated transmission of a corn mosaic virus in Hawaii by the corn lanternfly, *Peregrinus maidis* (Ashm.), proving transmission from corn to corn, but not from corn to sugar cane. Kunkel (11) reported the failure of *P. maidis* in North Carolina to transmit the virus of sugar cane mosaic of the United States to corn. These experiments lead to the conclusion that the corn mosaic virus of Hawaii (transmitted by *P. maidis*) is distinct from sugar cane mosaic virus in corn (transmitted by *Rhopalosiphum maidis*).

Stahl (24), described a stripe disease of corn in Cuba, which he transmitted with *Peregrinus maidis*, and stated that it was not identical with sugar cane mosaic.

Hadden (8), working on insect transmission of sugar cane mosaic virus in Hawaii, found that 2 insects transmitted the virus. The corn leaf aphid transmitted it from various grasses to cane and other grasses; the corn leafhopper from corn to corn, and in only one case from corn to Striped Tip cane. He assumed that this single transmission was accidental, and cited Stahl's conclusion that corn mosaic virus and sugar cane mosaic virus were distinct.

The foregoing review shows why most workers now believe that sugar cane mosaic and corn mosaic are caused by 2 different viruses: sugar cane mosaic virus has a fairly wide host range and can be easily transmitted from sugar cane to corn and back again with *Rhopalosiphum maidis*, whereas corn mosaic virus has not been transmitted from corn to sugar cane or any other host with *Peregrinus maidis*. So far as is known, corn mosaic virus does not occur in the United States and the sugar cane mosaic virus is only known to infect corn in areas where sugar cane is grown.

Wellman (28) showed that the virus of southern celery mosaic, later demonstrated by Price (24) to be a strain of cucumber virus 1, was infectious to corn and other members of the Graminaceae. In these experiments, the virus was transmitted by means of the cotton or melon aphid, *Aphis gossypii* Glover. In the same studies Wellman proved that the celery virus stripe on corn in Florida, caused by this strain of cucumber mosaic virus, was transmitted by aphids and not by *Peregrinus maidis*. This demonstrated that southern celery mosaic virus in corn is distinct from Stahl's (24) Cuban white stripe virus disease of corn.

In 1945 Frazier (6) described a streak disease of corn in California. The symptoms were sufficiently different from the known corn virus diseases to lead him to describe the disease and postulate the cause to be a virus. In the same year, Altstatt (2) described a similar disease occurring in Texas, and he believed the cause to be a virus. Using specimens from California and Texas, Kunkel (12, 13), described this disease as corn stunt, and proved it to be caused by a virus transmitted by the leafhopper, *Dalbulus maidis* (DeL. and W.). Prior to the present investigation, corn stunt was the only virus disease of corn reported from California.

MATERIALS AND METHODS.—Golden Bantam corn was used as the test plant. All seedlings were grown in standard flats, seed pans, or pots, and transplanted singly. To obtain best symptom expression of leaf fleck virus infection, the corn test plants were transplanted to larger pots as required. Plants used as sources of virus were transplanted to 7-in. pots and fertilized heavily when symptoms first appeared, in

[1] Accepted for publication September 13, 1952.

Based on a portion of a thesis submitted to the Graduate Division of the University of California, June 1949, in partial fulfillment of the requirements for the degree of Doctor of Philosophy. The author would like to thank J. H. Freitag for his encouragement and interest during the course of these investigations. The author gratefully acknowledges the help derived from the criticisms of the manuscript made by E. O. Essig, N. W. Frazier, J. H. Freitag, M. W. Gardner, F. O. Holmes, D. D. Jensen, and E. S. Sylvester.

[2] Assistant Plant Pathologist, Everglades Experiment Station, Belle Glade, Florida.

[3] The author is indebted to Professor E. O. Essig for determination of the aphid species used in this investigation.

order to keep them in a succulent condition favorable for feeding of the insect vectors.

Mechanical inoculation was attempted by 3 methods: the carborundum method of Rawlins and Tompkins (19, 20), Sein's (21) pinprick technique and Matz' (14) modification of Sein's method.

In the experiments involving insect vectors, the cages used to confine them to the test plants were of the type (cloth with glass window) described by Freitag (7) but modified so that the bottom opening of the cages was about 2½ in. in diameter; all the woodwork of the cages was unpainted. A strip of cotton large enough to cover the rim of the pot was folded over the rim before the cage was placed over the plant, to assure a positive seal and prevent escape of the insects. Cages of the same type, but of larger overall dimensions, were used to rear colonies of insects on large plants in large pots.

The insects were transferred in 3 ways: by leaf transfers, by camel's hair brush, and by jarring large numbers of the insects onto clean paper. The leaf transfer method was used mainly to establish or continue colonies used in the experiments.

In timed feeding experiments the insects were examined with a hand lens to determine whether or not they were actually feeding. The feeding time was kept with a stop-watch. The insects were considered to be feeding when they stopped wandering, placed the rostrum on the surface of the plant, held this position, became quiescent, and laid the antennae back. Often individuals met these conditions, but failed to feed continuously for the experimental time interval. Plants exposed to such insects were discarded; only those on which the vectors had fed continuously for the entire period were used. Except where noted, the insects were allowed access to the test plants for 24 hours. The plants were then fumigated with nicofume powder to kill the insects.

In the initial experiments, equal numbers of control and test plants were used. As no accidental spread occurred, only 20 per cent as many controls were used in subsequent trials.

To obtain noninfective aphids, apterae of field collections were caged on healthy young corn plants. The young of these insects were then transferred, within 8 hours after birth, to another healthy plant where they were allowed to mature and colonize. A test series of plants was fed upon by insects from these colonies to check noninfectivity. Similar periodical tests were conducted throughout the experiments to check these colonies of noninfective insects. No contamination occurred.

Infective insects were obtained by placing noninfectives from the colonies, or field collected insects, on diseased plants for several days, and using the apterae from these colonies.

Leaf fleck virus sources used throughout the investigations were diseased plants from each preceding test series. Therefore, these plants were actually insect subinoculations from the first field infectivity trials.

EXPERIMENTAL RESULTS: SYMPTOMS OF LEAF FLECK VIRUS INFECTION IN CORN.—The corn plants on which the following discussion of the symptoms of the leaf fleck disease is based, were insect inoculated when they were 10–14 days old. The largest percentage of the plants began to show symptoms 6 weeks after inoculation but the disease manifested itself as early as 4 weeks, and as late as 8 weeks. In general, the syndrome was complete 2 weeks after symptoms first appeared, or up to 3 weeks if the plants had started to tassel or slowed in their growth.

The first indication of the disease is the development of small, roughly circular, pale spots in the interveinal area of the tip of the oldest leaf (Fig. 1 B). These spots gradually enlarge to about 2 mm. in diameter, taking on a yellow hue. Then spots begin to appear toward the base of the leaf and may involve 1–2 in. of the leaf length daily. When the terminal third of the leaf is spotted, the tip and margins begin to burn. The tip burn then follows the spotting toward the base of the leaf at about the same rate. The marginal burn is very slow in developing and does not involve much more than ¼ in. on each side of the leaf. The burning is preceded by a yellowing of the leaf tissue in the initial phase. The yellow tissue turns orange in 3–4 days, and then becomes necrotic. As the burning progresses, the spots do not coalesce or in any way tend to produce streaking in the interveinal areas of the lamina of the leaf (Fig. 1, C). The first affected leaf is dead within 7–10 days after initial symptoms appear.

After symptoms appear in the basal leaf, a similar development is initiated in the next alternate leaf above. Thus there is a progression of the disease up the plant on alternate leaves as well as a progression of the symptoms in individual leaves. This vertical sequence is very regular and shows from the oldest to the youngest leaf, involving another leaf every 2 or 3 days. Consequently after a lapse of 2 or 3 weeks the leaves of the plant show various portions of the syndrome. If viewed from the bottom to the top of the plant, the leaves afford a graded series of symptoms, from death in the basal 2 or 3 leaves to the first development of flecking in 1 or 2 of the distal leaves. If the plant is observed in sunlight 2 or 3 weeks after initial symptoms are seen it presents an overall speckled or flecked appearance. This symptom suggested the name, leaf fleck, for the disease.

TESTS OF SEED TRANSMISSION OF CORN LEAF FLECK VIRUS.—Field plants of the Golden Bantam and Hickory King varieties with mature ears were selected as showing definite symptoms of the leaf fleck virus. To prove its presence the virus was transmitted from these field plants to healthy Golden Bantam seedlings in the greenhouse by *Rhopalosiphum prunifoliae*. Seed from the ears of plants that proved to have the virus by actual vector tests were planted and grown to maturity.

A total of 548 plants were grown, none of which developed symptoms of the disease. These data indicate that seed transmission of the leaf fleck virus probably does not occur.

MECHANICAL INOCULATION STUDIES.—Juice was extracted from above-ground portions of field collected plants, and inoculated by the carborundum method into 2 groups of 25 young corn seedlings. As a check, 25 seedlings were inoculated with distilled water and 25 with 10 apple grain aphids per plant from the diseased source plants. The only plants with symptoms of leaf fleck disease at maturity were 12 of the 25 check plants inoculated by means of *Rhopalosiphum prunifoliae*.

Another carborundum inoculation series was made using juice extracted from whole diseased plants, roots, and tops. All samples were centrifuged at 3000 r.p.m. for 1 hour, and then inoculated to 25 healthy corn seedlings. As a check, 25 plants were also inoculated with distilled water; all these plants grown to maturity were free from any disease symptoms. Twenty-five corn seedlings were inoculated both by Seins' (21) and Matz' (14) methods with whole plant juice. All 50 plants remained normal to maturity.

Attempts to transmit the virus to other plant species by the carborundum method were made with freshly extracted juice from the above-ground portion of experimentally infected corn plants. Five each of the following species were inoculated: Golden self-blanching celery *Apium graveolens* L., Turkish tobacco, *Nicotiana tabacum* L., Zucchini squash, *Cucurbita pepo* L., *Nicotiana glutinosa* L., sugar beet *Beta vulgare* L., and Early White Spine cucumber, *Cucumis sativus* L., none of which developed symptoms. All mechanical inoculations failed to transmit corn leaf fleck virus.

SOIL TRANSMISSION TESTS.—McKinney (15, 16) showed that viruses of winter wheat, winter rye, and winter oats were soil transmitted. Allen (1) showed that the virus of big vein of lettuce was soil borne in the absence of a vector. Smith (23) and Price (18) gave proof that plants could be infected with the virus of tobacco necrosis through the soil.

To test the possibility of soil transmission of the leaf fleck virus of corn the following experiments were conducted: crude juice was extracted from the washed roots of infected corn plants and 1 cc. aliquots of this juice were poured into the soil of each of 25 pots containing corn seedlings. All plants appeared normal at the end of 3 months. A similar experiment was set up using centrifuged juice from the whole plant, from tops only, and from the roots only. Not a single plant developed symptoms of the disease. These results indicate that soil transmission of the leaf fleck virus of corn does not occur.

TRANSMISSION TRIALS OF THE LEAF FLECK VIRUS BY APHID SPECIES.—The apple grain aphid, *Rhopalosiphum prunifoliae* was the only aphid found on field plantings of corn in the affected area from midseason 1947 until winter. In the early spring of 1948, 2 other species were found migrating to the spring corn plantings: the green peach aphid, *Myzus persicae* (Sulzer), and the English grain aphid, *Macrosiphum granarium* (Kirby). The corn leaf aphid, *Rhopalosiphum maidis* (Fitch) (Aphis)[4] has not been found in this area, but because it is frequently a serious pest on corn in other California locations it was included in the tests.

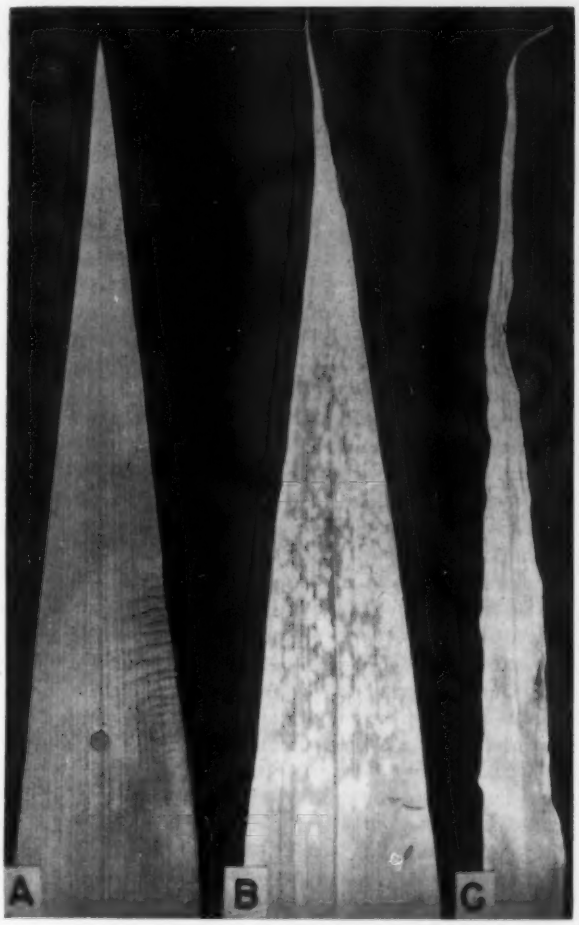


FIG. 1. A is tip of healthy corn leaf, B is tip of corn leaf showing initial spot or fleck symptom of leaf fleck virus infection, C shows further progress of the disease; note tip burn and beginning of marginal burn. All leaves are Golden Bantam. A and B × 1, C × ½.

Noninfective colonies of these 4 aphid species were obtained as described under materials and methods. Large populations of noninfective insects of each of the 4 species were caged separately on diseased plants, allowed to feed 4 days, and then 20 insects of each species were transferred to each of 25 corn seedlings. A comparable series of checks, using noninfective insects, were set up. The aphids were held on the test plants for 24 hours. The plants were then fumigated to kill the aphids, and held in the greenhouse for observation. After a lapse of 6 weeks, diseased plants were found in 3 of the 4 test series, while the checks remained normal (Table 1). A similar test was made with single insects of each of the 4 species; 25 plants were inoculated, and the results are also in Table 1.

[4] Specimens of this species were furnished to the author by R. A. Flock.

TABLE 1.—*Results of transmission trials of the leaf fleck virus by 4 species of aphids in groups of 20 and singly*

Aphid Species Used	20 Insects	Single Insect
Rhopalosiphum prunifoliae	12/25[a]	10/25
Myzus persicae	20/25	4/25
Rhopalosiphum maidis	15/25	13/25
Macrosiphum granarium	0/25	0/25

[a] The numerator indicates the number of diseased plants that developed in the experiment; the denominator indicates the number of plants inoculated in each test.

When *M. persicae* and *R. maidis* were transferred from a parent colony to a new host plant, mortality was very high. This resulted in erratic transmission. *R. prunifoliae* on the other hand lived well under experimental conditions. Large numbers could be obtained very rapidly and transfer of this species from plant to plant was easily accomplished. For these reasons it was used in most of the subsequent investigation.

Acquisition and inoculation thresholds.—Sylvester (25), working with the beet yellow-net virus, defined acquisition threshold as the minimum time required for a noninfective insect to acquire an infective charge of virus from a diseased plant, and inoculation threshold as the feeding time required for an infective insect to infect a healthy test plant.

In preliminary experiments, it was found that the leaf fleck virus could be acquired in 1 hour of feeding and transmitted to a healthy plant during the following hour. With this hour interval known for each threshold, it was possible to carry out more refined experiments.

Noninfective aphids were starved for 1 hour to promote quick feeding. They were then transferred by camel's hair brush to diseased plants; with the aid of a hand lens feeding was observed. Groups of 5 aphids were placed on each of the series of 5 test plants after periods of 5, 10, 15, 30, and 60 minutes of observed feeding. They were allowed access to the test plants for 24 hours. The plants were then fumigated to kill the aphids and placed in the greenhouse for observation. This series of 5 groups of 5 plants each was replicated 5 times. The 125 plants developed the disease to the extent shown in Table 2.

TABLE 2.—*The acquisition threshold of the leaf fleck virus of corn: groups of 5 noninfective Rhopalosiphum prunifoliae (Fitch) fed the indicated time intervals on a diseased plant, and then fed 24 hours on healthy plants*

	Test Feeding in Minutes				
Series	5 min.	10 min.	15 min.	30 min.	60 min.
1	0/5[a]	1/5	0/5	0/5	0/5
2	0/5	0/5	1/5	1/5	1/5
3	0/5	4/5	2/5	1/5	2/5
4	0/5	1/5	2/5	1/5	3/5
5	0/5	1/5	3/5	1/5	0/5
Totals	0/25	7/25	8/25	4/25	6/25

[a] The numerator indicates the number of diseased plants; the denominator, the number of plants inoculated.

Results show that a relatively constant proportion of plants developed the disease in each of the last 4 time groups. As a check, an additional series of 25 plants were run at the 5-minute time interval. No transmission resulted in this check series. It can be concluded that the acquisition threshold of the leaf fleck virus of corn lies between 5 and 10 minutes for this vector.

To determine the inoculation threshold required, numbers of *R. prunifoliae* reared on diseased plants were removed to a petri dish and starved for 1 hour to promote subsequent rapid feeding. In replicated series, groups of 5 starved infective insects were placed on healthy corn seedlings, and actually observed to feed for the time intervals of 5, 10, 15, 30 and 60 minutes as desired. A total of 125 plants were inoculated. One to 3 transmissions (Table 3) occurred in each group.

TABLE 3.—*Inoculation threshold of the corn leaf fleck virus: groups of 5 infective Rhopalosiphum prunifoliae (Fitch) fed upon healthy plants during the stated time intervals*

	Feeding Time in Minutes				
Series	5 min.	10 min.	15 min.	30 min.	60 min.
1	0/5[a]	2/5	0/5	1/5	3/5
2	1/5	3/5	2/5	2/5	1/5
3	0/5	3/5	0/5	2/5	3/5
4	1/4[b]	3/5	2/5	4/5	5/5
5	1/5	3/5	4/5	2/5	1/5
Totals	3/24	14/25	8/25	11/25	13/25

[a] The numerator indicates the number of diseased plants; the denominator the number of plants inoculated.
[b] One plant of this group of five died.

Since 3 transmissions were obtained at the 5 minute level another series of 25 plants was inoculated at this time interval, and only 1 of these 25 plants developed symptoms of the disease.

These experiments indicate that the inoculation threshold of the leaf fleck virus of corn is very close to 5 minutes.

Latent period.—The term latent period, as used herein, refers to the time interval which must elapse, after a noninfective aphid has fed upon a diseased plant for the time required to obtain an infective amount of virus (the acquisition threshold) and has fed upon a healthy test plant for the time required to infect this plant (the inoculation threshold), before the insect can infect the test plant. Therefore both thresholds must be subtracted from the total time required for transmission to obtain the *measurable* latent period.

The average time necessary for *R. prunifoliae* to settle and start feeding after transfer was 4.5 minutes. This is the interval described by Sylvester (25) as the pre-penetration time. Consequently this factor must be added each time a transfer is made. The individual insects were not observed; instead they were moved

TABLE 4.—*Results of latent period trials using groups of 5 Rhopalosiphum prunifoliae (Fitch) fed at varying intervals on both virus source plant and healthy test plant.*

Time on source plant (minutes)	Time on test plant (minutes)	No. plants tested	No. plants infected	Total time of test minutes[a]
5	5	25	3	19
10	5	25	1	24
10	10	25	3	29
15	15	25	3	39
30	30	25	3	69

[a] Total time of test includes a 4.5 minute correction factor which must be added each time vectors are transferred to allow the insects to settle and feed. Two transfers are made in this experiment, thus the total correction is 9 minutes.

in groups of 5 and the 4.5 minute interval allowed. At the end of all tests, the insects were counted and removed from the last corn plant.

Since the acquisition threshold was between 5 and 10 minutes, and the inoculation threshold was 5 minutes, a time interval of 5 minutes feeding on the virus source plant plus 5 minutes feeding on the healthy test plant was chosen as approaching the minimum time for transmission if no latent period existed. Experiments undertaken to determine the combined acquisition and inoculation thresholds indicated transmission could easily be obtained in 2 hours. Thus if a measurable latent period existed, it would lie within the 10–120 minute range. Replicated inoculations were made using various time intervals for combined acquisitions and inoculation and a 25 plant total was used for each interval.

The shortest time in which transmission was obtained was 19 minutes (Table 4). If the extreme low limits of the acquisition threshold and inoculation threshold are taken at 5 minutes each, then of the 19 minute total only 9 minutes could be a measurable latent period, but this exactly equals the correction factor, or pre-penetration time, added for the insects to settle and feed on both plants. This indicates there is no measurable latent period of the leaf fleck virus in the apple grain aphid.

Virus retention by the apple grain aphid.—Watson (26), and Watson and Roberts (27), separated viruses into 2 large classes termed persistent and nonpersistent. In the case of persistent viruses, the vectors retain their power to infect healthy plants for relatively long periods after an infective feeding. The nonpersistent viruses are lost from their vectors shortly after an infective feeding. Because the leaf fleck virus was not sap transmissible, and was known to be insect borne, tests were initiated to determine how long the aphid vectors retained the virus.

Groups of 20 infective apterae of *Rhopalosiphum prunifoliae* were placed on each of 5 healthy corn seedlings, then transferred daily to another set of healthy plants until all were dead (Table 5). The insects retained the virus for 9 days.

Retention experiments were also performed with *Myzus persicae*. The survival of this species on corn was poor. Nevertheless, several tests proved that this insect could retain the virus as long as it survived on corn under the conditions of the experiments, a period of 6 days. This demonstrated retention in the vectors, plus the failure of mechanical transmission, indicate that the leaf fleck virus is a persistent one.

HOST RANGE OF THE CORN LEAF FLECK VIRUS.—Host range investigations were carried out with *R. prunifoliae* as the insect vector. Members of the Graminaceae tested were: barley, *Hordeum vulgare* L; oat, *Avena sativa* L.; sugar cane, *Saccharum officinarum* L.; wheat, *Triticum vulgare* L.; and milo, *Sorghum vulgare* Pers. Two perennial grasses were also inoculated: Harding Grass, *Phalaris tuberosa* L., var. *stenoptera* (Hack) Hitch.; and sudan grass, *Sorghum vulgare* Pers. var. *sudanense* (Piper) Hitch. Other monocotyledonous plants tested were: freesia, *Freesia refracta* Klatt., in the Iridaceae; calla lily, *Zantedeschia aethiopica* Spreng., in the Araceae; and common onion, *Allium cepa* L., in the Liliaceae.

Dicotyledonous plants were also inoculated. Species tested were: Sugar beet, *Beta vulgare* L.; Zucchini squash, *Cucurbita pepo* L.; celery, *Apium graveolens* L.; and tobacco, *Nicotiana Tabacum* L.

All plants were inoculated with 10 aphids, reared on diseased corn plants. The insects were allowed access to the test plants in the series for 24 hours. Recovery of the virus was attempted only from those species which showed evidence of infection. Noticeable symptoms developed on only 3 species.

Barley and oat both showed similar indications of disease 6 weeks after inoculation. Small light colored flecks developed in the oldest leaves. A tip burn occurred, but only the distal ¼ in. of the lamina was involved. Both species of plants were cut back and fertilized. The new tillers, thus forced, showed the same symptoms and were in excellent condition to use as possible sources of virus. Recovery trials from both species of plants with groups of 10 noninfective apple

TABLE 5.—*Results of virus retention experiments: the first plant in each series had groups of 20 infective Rhopalosiphum prunifoliae (Fitch) transferred to them from a diseased corn plant and the survivors were transferred to another healthy plant daily.*

Series	Successive Days Aphids Were Transferred									
	1	2	3	4	5	6	7	8	9	10
1	20—	17—	16—	8+	7*	5+	3+	1+	1+	End
2	20—	20+	18—	8+	6+	5—	3+	2+	End	
3	20+	16+	16+	4+	3+	2+	1+	End		
4	20—	19+	17—	3+	End					
5	20+	16+	11—	7—	7—	4*	2—	1+	1+	End

Numbers at the left of each day column indicate the live insects transferred to that plant from the preceding plant. A plus (+) sign indicates that test plant became diseased, the minus (—) sign shown no disease developed in that plant, an asterisk (*) indicates death of the test plant. The word "End" shows the day all insects were dead and transfers were discontinued.

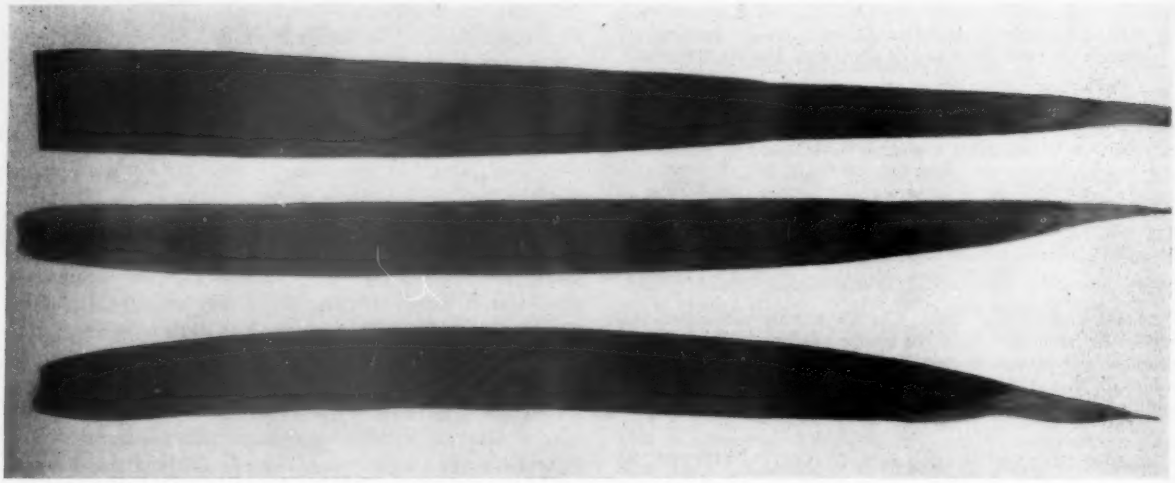


FIG. 2. Leaf blades of Harding grass showing flecking caused by infection with corn leaf fleck virus. Note absence of marginal burn, and basipetal progress of tip burn. Illustration × 1.

grain aphids did not succeed. Thus, even though the symptoms in barley and oat may have been due to the leaf fleck virus, the virus was not recovered.

Symptoms of the leaf fleck disease developed in the inoculated Harding grass and the virus was transferred back to corn from this host by means of non-infective apple grain aphids. The corn plants inoculated developed the typical symptoms of the disease. The results indicate that Harding grass is a host of the leaf fleck virus, and being a perennial could possibly serve as a natural source of the virus for early spring infection in corn. The average incubation period of the virus in Harding grass is the same as in corn, i.e., 6 weeks.

The symptoms of leaf fleck virus in Harding grass are not nearly so pronounced as in corn. The flecking of the lamina is lighter in color and the diameter of the spots is considerably less. Marginal leaf burn may fail to develop or may develop only a short distance basipetally from the tip burn. The orange coloration of the tip of the leaf as described for corn fails to develop, and only the very lowest blades on each tiller are killed. At a distance the infected plants appear lighter green than normal. Close examination shows this to be due to the many lighter colored flecks in the individual blades (Fig. 2).

Fifteen varieties of field and pop corns were tested to determine their susceptibility to the leaf fleck virus. Ten plants of each variety were each inoculated with a group of 10 infective apple grain aphids confined on the test plants 24 hours. Among the yellow field corn strains, infection was obtained on DeKalb 627, 2 out of 10; DeKalb 804, 3 out of 10; DeKalb 847, 1 out of 10; DeKalb 1025, 3 out of 10; and Pioneer 341, 1 out of 10. No infection occurred on DeKalb 404A, Pioneer 330, Vinton 33 and 34A.

Two strains of white field corn were infected as follows: Pioneer 505, 2 out of 10; and Hickory King, 3 out of 10. Four strains of popcorn were tested and showed infection as follows: Pinky, 2 out of 10; White Rice, 2 out of 10; Jap Hulless, 2 out of 10; Dynamite South American, 2 out of 10. Three of the 10 Golden Bantam checks were infected in this series of tests.

Virus diseases of maize reported from locations outside the continental United States listed by Holmes (9) and Smith (22) can be clearly separated from the leaf fleck disease by combinations of differences of vectors, symptoms, host ranges etc. It is therefore believed that the leaf fleck disease of maize is caused by a hitherto undescribed virus.

The characteristics of this virus generally conform to those of the family Marmoracae of Holmes (9), and although the symptoms produced by the virus in its known host plants are not altogether representative of those of the genus *Corium*, most of its other characteristics are. Therefore the binomial *Corium zeae* is proposed.

Technical description.

Corium zeae n. sp.

Common name: Maize leaf-fleck virus.

Known hosts: Graminaceae-*Zea mays* L., several varieties of field, sweet and pop corn; *Phalaris tuberosa* L. Var. *stenoptera* (Hack.) Hitch. Harding grass.

Syndrome in maize: Pale yellow circular spots about 2 mm. in final diameter develop first in distal portion of the older leaves 6 to 8 weeks after inoculation with an infective aphid vector. These spots develop progressively toward the base of the leaf. Leaf tip and marginal burning follow in order after the development of the initial spotting symptoms, and the entire leaf dries and dies to the stalk. These symptoms appear in alternate leaves up the plant in the same order until the entire syndrome may be seen in the plant 10 days to 2 weeks after symptoms are initiated.

Transmission: The virus is transmitted by 3 aphid species, *Rhopalosiphum prunifoliae* (Fitch), *Myzus persicae* (Sulz), and *Rhopalosiphum maidis* (Fitch). It is not mechanically transmissible when freshly ex-

tracted whole plant juice from diseased plants is used nor does infection occur when whole plant juice expressed from diseased plants is added to the soil in which healthy plants are growing. Transmission of the virus in seeds taken from diseased plants does not occur.

Virus retention of the vectors: The virus is retained by *R. prunifoliae* and *M. persicae* for their entire lives under experimental daily transferring.

Acquisition and inoculation thresholds: Tests using *R. prunifoliae* as the vector show that the acquisition threshold of the virus for this species lies between 5 and 10 minutes and that the inoculation threshold of the virus for the same aphid is 5 minutes.

Latent period: No measurable latent period is demonstrated for this virus by the vector *R. prunifoliae*.

Descriptive habitat: The northeast shore area of San Francisco Bay including the cities of San Pablo, Albany, El Cerrito, Berkeley and Oakland, California, U. S. A.

SUMMARY

Leaf fleck, a hitherto unreported persistent aphid borne virus affecting corn, *Zea mays* L., is herein described as a new species *Corium zeae*, under Holmes' classification system. Symptoms of the disease are given, and an experimental host range reported. The virus is not mechanically transmissible, nor is it carried in the seed produced by infected plants. Transmission of the virus did not occur through the soil. Three aphid species, *Rhopalosiphum prunifoliae* (Fitch), *Rhopalosiphum maidis* (Fitch), and *Myzus persicae* (Sulz.), are demonstrated vectors of the virus. Acquisition and inoculation thresholds, latent period, and retention by the insect vector are discussed. The type locality of the virus is the northeast border of San Francisco Bay, California, U. S. A.

Division of Entomology,
University of California,
Berkeley, California

LITERATURE CITED

1. Allen, M. W. 1948. Relation of soil fumigation, nematodes, and inoculation technique to big vein disease of lettuce. Phytopathology **38**: 612-627.
2. Altstatt, G. E. 1945. A new corn disease in the Rio Grande Valley. U. S. Dept. Agr. Pl. Dis. Rptr. **29**: 533-534.
3. Brandes, E. W. 1919. The mosaic disease of sugar cane and other grasses. U. S. Dept. Agr. Bul. 829. 1-26.
4. Brandes, E. W. 1920. Mosaic disease of corn. Jour. Agr. Res. [U. S.] **19**: 517-522.
5. Brandes, E. W., and P. J. Klaphaak. 1923. Cultivated and wild hosts of sugar-cane or grass mosaic. Jour. Agr. Res. [U. S.] **24**: 247-262.
6. Frazier, Norman W. 1945. A streak disease of corn in California. U. S. Dept. Agr. Pl. Dis. Rptr. **29**: 212-213.
7. Freitag, J. H. 1936. Negative evidence on multiplication of curly-top virus in the beet leafhopper, Eutettix tenellus. Hilgardia **10**: 305-342.
8. Hadden, F. C. 1928. Sugar cane mosaic and insects. Hawaiian Planters' Record **32**: 130-142.
9. Holmes, F. O. 1948. Order Virales. The filterable viruses. Bergey's manual of determinative bacteriology. Ed. 6. Supplement No. 2: 1127-1286. Baltimore.
10. Kunkel, L. O. 1922. Insect transmission of yellow stripe disease. Hawaiian Planters' Record. **26**: 58-64.
11. Kunkel, L. O. 1927. Corn mosaic of Hawaii distinct from sugar cane mosaic. (Abs.) Phytopathology **17**: 41.
12. Kunkel, L. O. 1946. Leafhopper transmission of corn stunt. Proc. Nat. Acad. Sci. [U. S.] **32**: 246-247.
13. Kunkel, L. O. 1948. Studies on a new corn virus disease. Arch. ges. Virusforsch. 4: 24-46.
14. Matz, J. 1933. Artificial transmission of sugar cane mosaic. Jour. Agr. Res. [U. S.] **46**: 821-839.
15. McKinney, H. H. 1925. A mosaic disease of winter wheat and winter rye. U. S. Dept. Agr. Bul. 1361. 1-10.
16. McKinney, H. H. 1946. Mosaics of winter oats induced by soil borne viruses. Phytopathology **36**: 359-369.
17. Price, W. C. 1935. Classification of southern celery-mosaic virus. Phytopathology **25**: 947-954.
18. Price, W. C. 1938. Studies on the virus of tobacco necrosis. Am. Jour. Bot. **25**: 603-612.
19. Rawlins, T. E., and C. M. Tompkins. 1934. The use of carborundum as an abrasive in plant virus inoculations. (Abs.) Phytopathology **24**: 1147.
20. Rawlins, T. E., and Tompkins, C. M. 1936. Studies on the effect of carborundum as an abrasive in plant virus inoculations. Phytopathology **26**: 578-587.
21. Sein, F., Jr. 1930. A new mechanical method for artificially transmitting sugar cane mosaic. Jour. Dept. Agr. Puerto Rico **14**: 49-68.
22. Smith, K. M. 1937. A textbook of plant virus diseases. P. Blakiston's Son and Co., Inc., Philadelphia. 615 pages.
23. Smith, K. M. 1937. Further studies on a virus found in the roots of certain normal-looking plants. Parasitology **29**: 86-95.
24. Stahl, C. F. 1927. Corn stripe disease in Cuba not identical with sugar cane mosaic. Trop. Plant Res. Found. Bul. **7**: 1-12.
25. Sylvester, E. S. 1949. Transmission of sugar beet yellow-net virus by the green peach aphid. Phytopathology **39**: 117-132.
26. Watson, M. A. 1946. The transmission of beet mosaic and beet yellows viruses by aphids; a comparative study of a non-persistent and a persistent virus having host plant and vectors in common. Proc. Roy. Soc. (London) **B, 133**: 200-219.
27. Watson, M. A., and F. M. Roberts. 1939. A comparative study of the transmission of Hyoscyamus virus 3, potato virus Y and cucumber virus 1 by the vectors Myzus persicae (Sulz.) M. circumflexus (Buckton) and Macrosiphum gei (Koch). Proc. Roy. Soc. (London) **B, 127**: 543-577.
28. Wellman, F. L. 1934. Infection of Zea mays and various other Gramineae by the celery virus in Florida. Phytopathology **24**: 1035-1037.

PHYTOPATHOLOGICAL NOTES

The Formation of Rod-Shaped Particles Resembling Tobacco Mosaic Virus by Polymerization of a Protein from Mosaic-Diseased Tobacco Leaves. WILLIAM N. TAKAHASHI AND MAMORU ISHII. An abnormal macromolecular protein, other than the virus nucleo-protein, was shown by Takahashi and Ishii[1] to be present in specially prepared extracts of mosaic tobacco leaves. It was suggested that this protein might possibly be a relatively stable intermediate stage in the formation of tobacco mosaic virus. In the work described below this protein has been induced to polymerize in the absence of living cells into rod-shaped particles. These particles resemble tobacco mosaic virus particles in several respects.

The method of extraction giving the highest yield of the protein, 2.4 per cent of the total leaf protein including the virus, was the so-called used ether-water method of Chibnall, Miller, Hall and Westfall[2] followed by freeze pounding. Briefly, the principal steps were as follows: fresh leaves were cytolysed by immersing them in used ether-water. The vacuolar sap was pressed out and the leaf pad washed several times with cold water until the press water was clear and colorless. Next the pad was cut into strips, soaked with buffer to maintain a pH of 7.0, then frozen. While still frozen the strips were passed through a food chopper and the frozen macerate was pounded to a fine powder in a mortar. Finally, the powdered tissue was thawed, then extracted with several volumes of buffer, pH 7.0.

From the combined extract the abnormal protein was isolated as follows: the extract was first cleared of gross plant tissue debris by centrifugation at 10,000 × g.; most of the virus particles were then eliminated by ultra-centrifuging the supernatant liquid at 100,000 × g.; to this supernatant liquid sufficient ammonium sulfate crystals were added to make 38 per cent ammonium sulfate. The resulting precipitate was centrifuged down, then redissolved in buffer maintained at pH 7.0. A comparison of electrophoretic diagrams of such extracts from mosaic and healthy tobacco leaves showed the presence of an odd component in the mosaic extract. This fraction will be referred to hereafter as the X component or X protein.

The protein mixture was ultracentrifuged a second time and a clear, colorless pellet was thrown down. Prior treatment with ammonium sulfate, apparently rendered certain protein components sedimentable by ultracentrifugation. Electrophoretic analysis and subsequent electron micrography revealed these components to be the X component and short virus rods. With only 1 contaminant, short virus, present the abnormal protein was easily separated from it by prolonged electrophoresis in a separation cell.

This X component gave a positive Biuret, positive Millon, and after hydrolysis a positive nonhydrin reaction. It gave a slight orcinal but negative Molisch and phosphorus test. Its ultraviolet absorption maximum was at 280 mμ. These tests indicate that the substance is a protein but not a nucleoprotein. Its isoelectric point as determined by isoelectric precipitation was in the pH range 3.8-4.1 as compared to pH 3.9 for that of the strain of tobacco mosaic virus used in these ex-

[1] Takahashi, William N., and Mamoru Ishii. 1952. An abnormal protein associated with tobacco mosaic virus infection. Nature 169: 419-420.

[2] Chibnal, Charles A., Ernest J. Miller, Donald H. Hall, and Ronald G. Westfall. 1933. CCLVI. The protein of grasses. II. A new method of preparation. Biochem. Jour. 27: 1879-1884.

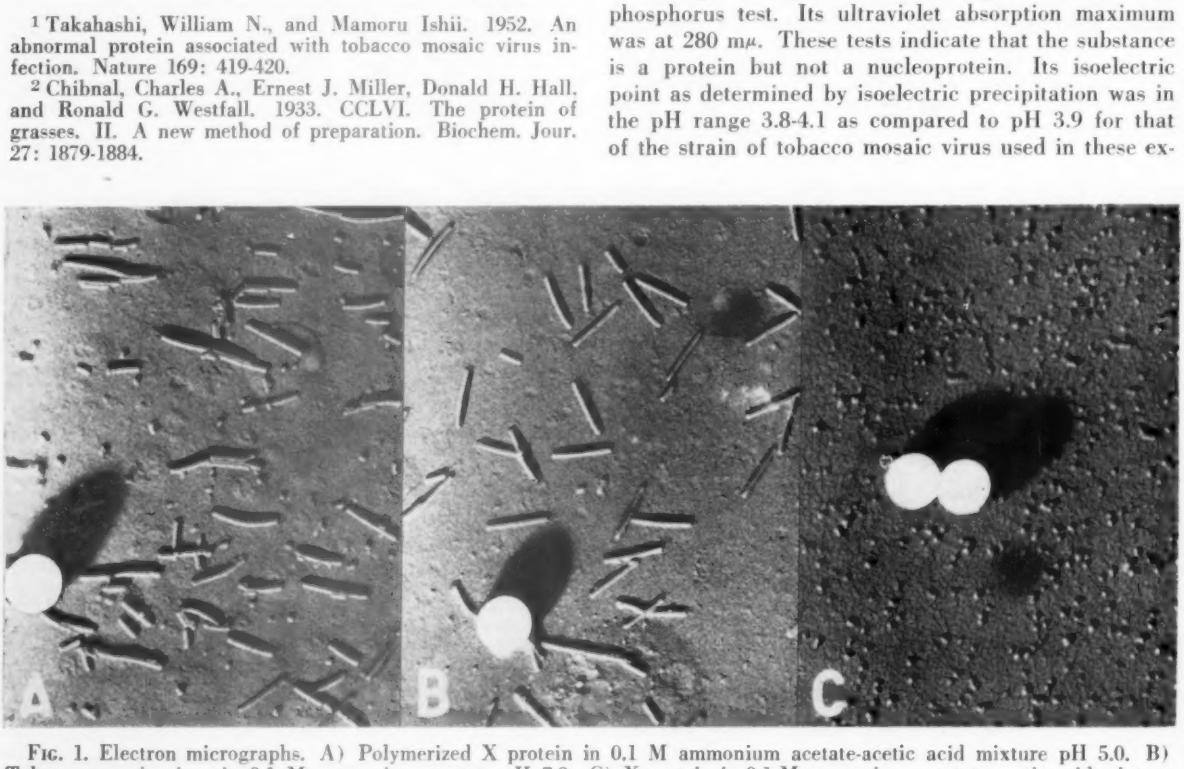


FIG. 1. Electron micrographs. A) Polymerized X protein in 0.1 M ammonium acetate-acetic acid mixture pH 5.0. B) Tobacco mosaic virus in 0.1 M ammonium acetate pH 7.0. C) X protein in 0.1 M ammonium actetate-acetic acid mixture pH 7.0. The polystyrene latex indicator spheres are approximately 260 mμ in diameter.

periments. The migration rate of the protein in the 0.1 ionic strength cacodylate buffer, pH 7.0, was 4.0 $\times 10^{-5}$ cm./sec./volt/cm. On the other hand the mobility of the short virus was 7.5×10^{-5} and that of the typical 15 $\times$ 300 mμ tobacco mosaic virus 7.8×10^{-5}. Positive cross precipitin reactions as well as homologous reactions were shown when the X protein and purified tobacco mosaic virus were mixed with rabbit antisera for purified tobacco mosaic virus and X protein respectively.

The virus antigen was prepared by 4 alternate cycles of low and high speed centrifugations of press juice from mosaic tobacco plants. By present standards virus prepared by such a procedure has been considered to be pure.

The formation of discrete rod-shaped particles from the electrophoretically isolated X component was readily brought about by adding 0.15 ml of a 0.2 per cent solution of the protein to 0.5 ml of a 0.1 M ammonium acetate solution adjusted to pH 5.0. In a few minutes the mixture took on a definite blue white opalescence similar to that of dilute purified tobacco mosaic virus. This opalescence and polymerization can be reversed by readjusting the pH to 7.0 or dialysing against distilled water.

The rod-shaped particles produced from the X component at pH 5.0 are shown in Fig. 1A. These bear a close morphological resemblance to the tobacco mosaic virus in Fig. 1B. In both plates particles longer and shorter than the typical 300 mμ virus particles are found. There are 300 mμ particles in each plate, but more in Fig. 1B. In both cases the width of the particles is 15 mμ. The particles of the unpolymerized X protein at pH 7.0 appear to be approximately spherical and around 15 mμ in diameter. (Fig. 1C) However, the remarkable smoothness in the outline of the rods formed from the X component suggests the possibility that the unpolymerized X protein particles may actually be very labile in form or more like discs or very short cylinders.

Infectivity tests on *Nicotiana glutinosa* of both the unpolymerized and polymerized X protein have given negative results. There is a possibility however, that infectivity could be imparted to this noninfective particle if an appropriate nucleic acid could be incorporated into it during or after the process of polymerization.

A relationship between the X protein and tobacco mosaic virus is suggested by a similarity in certain chemical, physical chemical, and serological properties. The polymerization of the X protein into discrete, rod-shaped particles of the same diameter as the virus further suggests that the structure and protein moiety of the virus particle may be built up by an orderly arrangement of the X protein. Further work is being conducted in an attempt to test this hypothesis.—Department of Plant Pathology, University of California, Berkeley 4, California.

The Formation of Perithecia of Chalara quercina in Nature in West Virginia.[1] J. M. STALEY AND R. P. TRUE. Since their discovery by Bretz,[2] perithecia of *Chalara quercina* have been recognized as potential sources of infection in long distance transmission of oak wilt. Although perithecia have been found in nature in Illinois[3] there have been no published reports of the conditions under which they are formed in nature. Hepting et al[4] have described the sexuality and compatibility of the fungus in artificial culture and have pointed out the possible significance of the perithecia and ascospores in insect or bird transmission. Recently Barnett, Staley, and True[5] have shown that the mycelial mats formed beneath the bark are ready for spermatization and form perithecia promptly when spermatized with conidia of the opposite compatibility group. Leach, True, and Dorsey[6] have shown that spermatization can be accomplished through the agency of insects and have described the mechanism by which the process may be accomplished in nature. After these demonstrations it seemed advisable to examine carefully a number of trees killed by wilt in 1951, for the occurrence of perithecia.

In mid-April, 1952, several infected trees dead or dying from oak wilt had been visited and samples of mycelial mats collected for laboratory study. A mat from a scarlet oak tree, in Boone County, West Virginia, when spermatized on opposite ends with conidia of the 2 different compatibility groups, produced perithecia as a result of both spermatizations. On May 5 a second visit was made to this tree. Perithecia were found and brought to the laboratory where microscopic examination of the spore masses showed typical ascospores of *Chalara quercina.* Mycelium from these ascospore masses grown on agar medium produced typical endoconidia. Further observations have revealed the presence of perithecia in nature on 5 of 7 recently killed red and scarlet oak trees examined in widely separated regions of the state.

The beaks of the perithecia were usually the only portion visible. These were almost entirely black except for slightly lighter coloration on the tips of the beaks which were partially hidden by the exuding spore masses. The spore masses were larger than those produced in the laboratory on weak maltose casein hydrolysate medium, and had less tendency to cling in a rounded mass on the beak. The spore masses were

[1] Published with the approval of the Director of the West Virginia Agricultural Experiment Station as Scientific Paper No. 459.

[2] Bretz, T. W. The perithecial stage of *Chalara quercina* Henry. (Abs.) 1952. Phytopathology 42: 3.

[3] Tehon, L. R. 1952. Personal correspondence.

[4] Hepting, G. H., E. R. Toole and J. S. Boyce, Jr. 1951. Perithecia produced in an unpaired isolate of *Chalara quercina* and its possible significance in oak wilt control. U. S. Dept. Agr. Plant Dis. Reptr. 35: 555.

[5] Barnett, H. L., J. M. Staley and R. P. True. 1952. Mycelial mats of *Chalara quercina* on killed oak trees as a potential source of perithecia in nature. Phytopathology 42: 531-532.

[6] Leach, J. G., R. P. True and C. K. Dorsey. 1952. A mechanism for liberation of spores from beneath the bark and for diploidization in *Chalara quercina.* Phytopathology 42: 537-540.

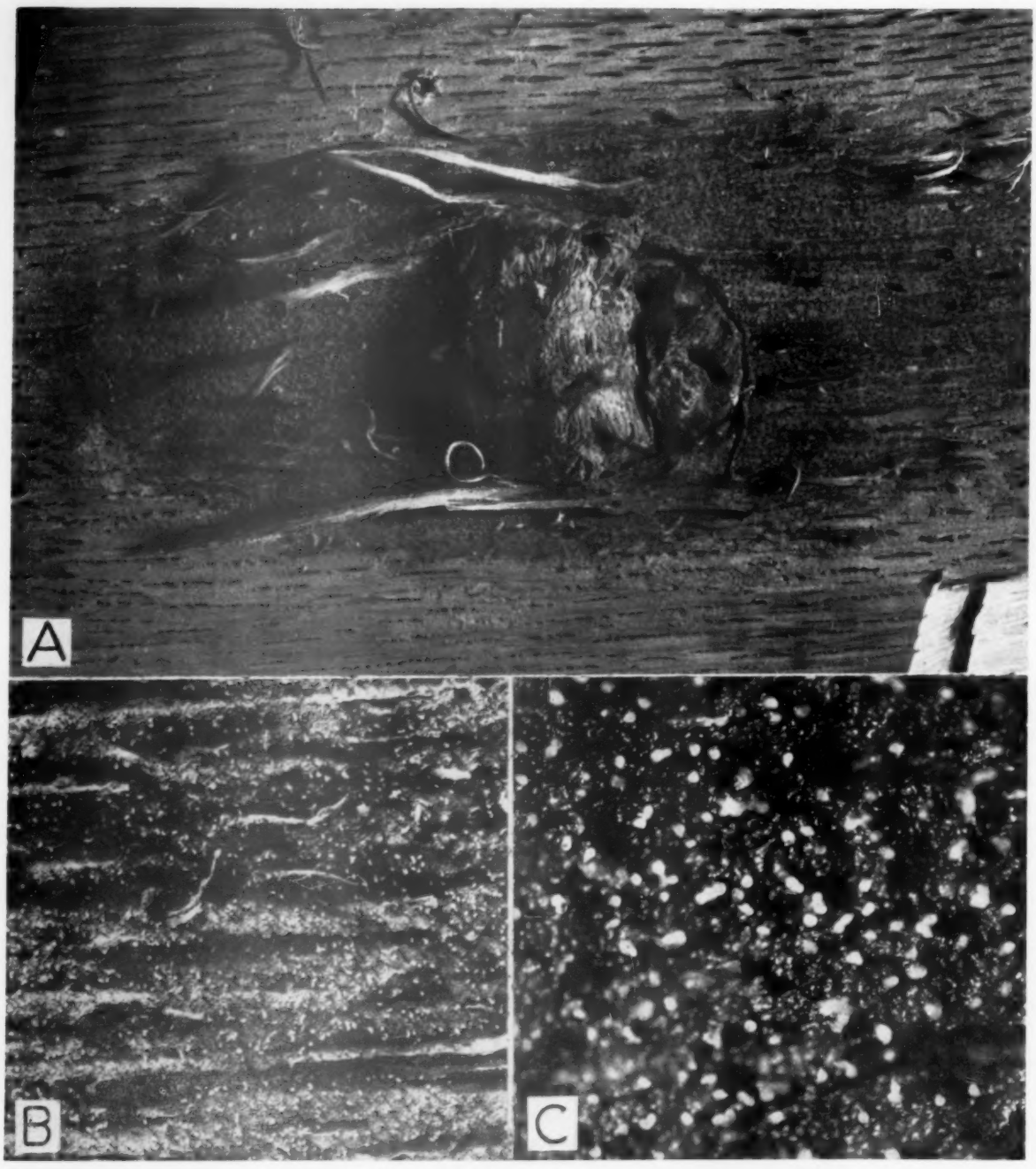


FIG. 1. The development of perithecia of *Chalara quercina* in nature. A) A single large mat showing the cushion that ruptured the bark exposing the mycelium, upon which perithecia have developed in abundance. Approx. 1×. B) Perithecia on the wood surface magnified approximately 2½×. C) A higher magnification showing the white globular masses of ascospores as they appear on the beaks of the perithecia. About 10×.

quite readily seen against the darker mat background. (Fig. 1) The mats on which the perithecia were found seemed to have passed the peak of their development and a darker coloration was becoming evident. The perithecia were not found on the central portion of the mat but rather on the adjacent heavy mycelial growth. Perithecia were produced on both the wood and bark but were found in larger numbers on the wood surface. All mats showing perithecia had been exposed to possible insect vectors through splits in the bark layers, and several species of insects were found in close association with the ascospores.

Oak wilt surveys conducted during 1951 found 54 known oak wilt trees at 45 infection centers, 34 of

which are separated by distances of at least 1 mile from any other known oak-wilt tree. Of the 31 mapped disease centers, 17 contained single diseased trees surrounded only by healthy oaks and other species. No infected areas of large extent have been found. This indicates that while root graft transmission has probably played a part in some infections, it has not yet become of primary importance in the development of the disease in the West Virginia area. In this area vector spread still seems to be the principal means of transmission.

The finding of perithecia occurring in nature on several isolated trees in widely separated localities offers further support to the concept that the perfect stage plays an important role in the spread of the disease in West Virginia.—Department of Plant Pathology and Bacteriology, West Virginia University, Morgantown, West Virginia.

A New Method for Application of Chloropicrin in Warehouse Fumigation.[1] NORMAN D. DOBIE, ROY A. YOUNG, J. B. RODGERS AND J. A. MILBRATH.[2] Chloropicrin has been recommended for fumigation of sweet potato storage houses.[3] A temperature above 70° F. and a relative humidity approaching saturation were necessary before maximum effectiveness of chloropicrin against fungi was attained. To obtain these conditions and to disperse chloropicrin as thoroughly as possible, the standard practice has been to seal all outside openings, to wet down all inside surfaces of storage houses with water, and to raise the temperature to at least 70° F. When the humidity is near saturation and when the temperature is at the desired level, chloropicrin is poured over crumpled sacks which have been draped over boxes, or hung on walls or posts to facilitate more rapid dispersion of the gas. The recommended dosage for this method of application is 1 lb. of chloropicrin per 1000 cu. ft. of empty storage space; the cost is approximately one dollar per 1000 cu. ft.

In Oregon there are many large potato and nursery storage houses well over 100,000 cu. ft. in volume. Disinfestation of these large houses with chloropicrin, using the sack method, is costly in both time and materials. In attempting to reduce the amount of material required for treatment, trials were conducted in which chloropicrin was introduced into storage houses by steam injection, using a specially designed venturi nozzle. Use of thermo-aerosol fumigation seemed desirable since the steam would raise the temperature and humidity of the storage space and would aid in dispersion and volatilization of chloropicrin.

[1] Published with the approval of the director of the Oregon Agricultural Experiment Station as Technical Paper No. 752, contribution from Department of Botany and Plant Pathology.

[2] Graduate Research Assistant in Plant Pathology, Associate Plant Pathologist, Professor Agricultural Engineering, Plant Pathologist respectively, Oregon Agricultural Experiment Station.

[3] Nusbaum, C. J. 1944. The use of chloropicrin in sweet potato storage-house fumigation. Reprinted in The Larvacide Log 7(1) August: 20-21.

[4] The steam generator used in this research was furnished by the Besler Corporation, Oakland, California.

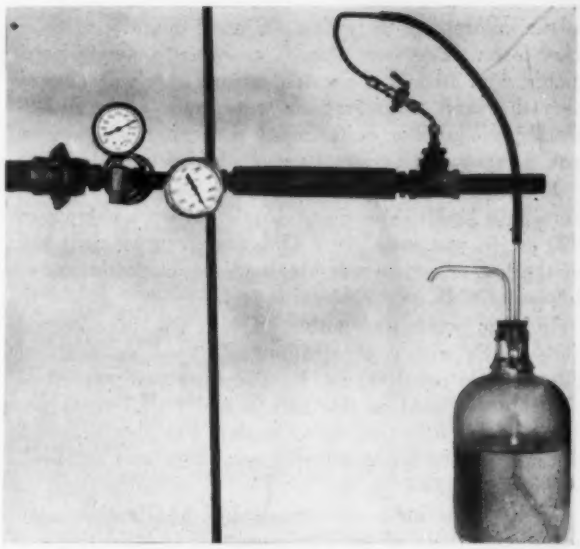


FIG. 1. The venturi nozzle with venturi lead-in tube and valve connection attached to the fumigant container.

The new method described here may be considered a thermo-aerosol fumigation process. The same general procedures of preparing the building were followed as are used in the sack method. In producing the thermo-aerosol a flash type steam generator was used,[4] but other types of machines capable of producing large quantities of steam should be equally satisfactory. Steam from the flash generator was led into the storage house through a high pressure steam hose, the discharge end of which was equipped with a venturi nozzle. The nozzle increased the discharge velocity of the steam and facilitated pickup and vaporization of the chloropicrin.

In fumigating a storage house the nozzle was inserted into the building through a hole 1 in. in diameter. Steam was forced into the building to raise the temperature and humidity to the desired levels. Then the actual fumigation was initiated by attaching the venturi lead-in tube to a rubber hose connected to a siphon apparatus in a gallon jug containing chloropicrin (Fig. 1).

The passage of steam through the venturi created a vacuum which drew the chloropicrin into the steam being discharged into the storage house. The rate of flow of the chloropicrin into the venturi was regulated by clamp or valve connections at a point between the steam hose and the vessel containing the fumigant.

Fusarium roseum (Link) Snyder & Hansen was used to test the effectiveness of storage house disinfestation with chloropicrin applied in steam. Conidia from 5- to 10-day-old test tube cultures were suspended in sterile distilled water, then thoroughly mixed with autoclaved sand. A ¼-in. layer of the mixture was placed in petri dishes which were placed in various locations throughout the building to be fumigated, and exposed to the air just prior to fumigation. After the 24-hour period of fumigation, the plates were returned

to the laboratory for testing. A small quantity of sand from each plate was placed in separate sterile petri dishes, and 10 ml. of potato-dextrose agar was poured over the sand. Observations were made at 1- and 2-week periods after culturing to determine whether or not the spores at various locations had been killed.

For testing the efficiency of the chloropicrin thermo-aerosol, a small experimental unit having a volume of 250 cu. ft. was used. In preliminary tests efficient kill of the test organism was obtained at concentrations as low as 1/27 lb. per 1000 cubic feet.

In large potato warehouses efficient kill was obtained consistently with concentrations of 68 ml. or ¼ lb. of chloropicrin per 1000 cu. ft. The approximate cost of chloropicrin used at this rate would be 25 cents per 1000 cu. ft. Effective disinfestation was obtained in 5 out of 7 houses fumigated with concentrations of 34 ml. or ⅛ lb. per 1000 cu. ft.

Using a thermo-aerosol method of application, optimum conditions of both temperature and relative humidity for effective use of chloropicrin can be readily obtained. The fumigation is much less hazardous since the operator remains outside the building during the fumigation process, yet the chloropicrin is dispersed throughout the building. The complete fumigation operation can be effected in considerably less time than is possible with other methods and requires approximately ¼–⅛ as much fumigant for effective kill of a test organism as that recommended for use with other methods of application.—Oregon Agricultural Experiment Station, Corvallis, Oregon.

Two Races of Fusarium oxysporum f. perniciosum Causing Wilt of Albizzia spp. E. RICHARD TOOLE. *Fusarium oxysporum* f. *perniciosum* causes a vascular wilt of the mimosa tree (*Albizzia julibrissin* Durazz.).[1] A similar wilt of *A. procera* (Roxb.) Benth., was reported from Puerto Rico in 1945.[2] In 1947, Dr. L. A. Alvarez of the Agricultural Experiment Station, Puerto Rico, isolated a fungus from discolored vascular tissue of wilting *A. procera* trees. He sent a culture to the writer, who identified it as *Fusarium oxysporum* f. *perniciosum*.

In 1947, the writer tested the pathogenicity of this isolate to *Albizzia julibrissin*, by inoculating seedlings of *A. julibrissin* with the isolate from *A. procera*. The roots were dipped into a spore suspension of the fungus and the seedlings were then planted in a sandy soil in small containers in the greenhouse. Other seedlings of *A. julibrissin* were inoculated similarly with an isolate from *A. julibrissin* and then planted. Two and a half months after inoculation, all seedlings that had not wilted were pulled and examined for vascular discoloration. Wilting and vascular discoloration were produced only by the isolate from *A. julibrissin* (Table 1).

In 1948, another inoculation experiment was undertaken, with seedlings of *Albizzia julibrissin*, *A. procera*, and *A. moluccana* Miq. Some seedlings were inoculated with an isolate from *A. julibrissin* and others with the isolate from *A. procera*. This experiment was terminated after 3½ months. Neither of the isolates was pathogenic to *A. moluccana;* the isolate from *A. julibrissin* was pathogenic only to *A. julibrissin*, and the isolate from *A. procera* only to *A. procera* (Table 1).

Since clear differences in pathogenicity exist between the form attacking *Albizzia julibrissin* and the one attacking *A. procera*, it seems desirable to differentiate between them in nomenclature. It is proposed that the form causing vascular wilt of *A. julibrissin* be named Race 1 as follows:

Fusarium oxysporum Schlect. emend. Snyder and Hansen forma *perniciosum* (Hepting) **Toole Race 1.**

It is further proposed that the form causing vascular wilt in *Albizzia procera* be named Race 2 as follows:

Fusarium oxysporum Schlect. emend. Snyder and Hansen forma *perniciosum* (Hepting) **Toole Race 2.**—Division of Forest Pathology, U. S. Department of Agriculture, Asheville, N. C.

[1] Snyder, W. C., E. R. Toole, and G. H. Hepting. 1949. Fusaria associated with mimosa wilt, sumac wilt, and pine pitch canker. Jour. Agr. Res. [U.S.] 78: 365-382.

[2] Annual report of the Tropical Forest Experiment Station for the year 1944. U. S. Forest Service, Puerto Rico, Jan. 25, 1945. (mimeographed).

TABLE 1.—*Susceptibility of some species of Albizzia to 2 races of Fusarium oxysporum f. perniciosum*

Year of experiment	Species	*Fusarium oxysporum* f. *perniciosum* on *A. julibrissin* (Race 1)		*Fusarium oxysporum* f. *perniciosum* on *A. procera* (Race 2)		Control	
		Seedlings inoculated	Seedlings[a] wilted	Seedlings inoculated	Seedlings[a] wilted	Seedlings used	Seedlings wilted
		Number	*Number*	*Number*	*Number*	*Number*	*Number*
1947	*Albizzia julibrissin*	8	8	8	0	8	0
1948	*Albizzia julibrissin*	10	8	10	0	5	0
	Albizzia moluccana	8	0	8	0	4	0
	Albizzia procera	10	0	10	6	5	0

[a] The original fungus was reisolated from wilted seedlings.

INDEX FOR VOLUME 42

AUTHOR AND SUBJECT INDEX. New species and varieties in boldface type. Junior authorship indicated by pages in parentheses.

ABBOTT, E. V., 281
Acer negundo, tobacco ringspot virus on, 478
Acidity, see Hydrogen-ion concentration
Actidione, see Antibiotics, and Fungicides: actidione
ADSUAR, JOSE, (3)
AFANASIEV, M. M., 101
Agallia constricta (leafhopper), multiplication of wound tumor virus in, 269
Agalliana ensigera (leafhopper), vector for new strain of tomato curly top virus, 396
  sticticollis, vector for new strain of tomato curly top virus, 396
Age of host, relation to susceptibility of tomato to bacterial wilt, 631
  effect of safflower root rot development, 220
Agrobacterium rubi, eastern blueberry gall strain, description, 90
  tumefaciens, morphological varients, 8
    western blueberry gall strain, description, 90
Air-borne spores, distribution hypothesis, 323
AKELEY, R. V., (277)
Albizzia spp. (mimosa), Fusarium wilt, 694
Albugo candida, on horseradish, 109
  occidentalis, factors in pathogenesis, 17
    morphology and pathogenicity, 473
    on spinach, factors affecting development, 448
Aleurites montana, see Tung
ALEXANDER, L. J., 463, (467)
Alfalfa (Medicago sativa),
  bacterial wilt, maintenance of virulent inoculum by deep-freeze method, 13
  black stem, seed loss, 468
  crown bud rot, disease complex, 510
  crown rot, identification of incitant, 513
  damping-off, seed treatments, 22
    and root rot, control, 613
  mosaic virus, aphid transmission, 261
    strains in potato, 516
  Pierce's disease, vectors, 533
  Sclerotium rolfsii on, 1
  Volutella sp. parasitic on, 5
  witches' broom, 649
ALLARD, R. W., (515)
ALLEN, O. N., (613)
ALLEN, PAUL J., 483
ALLISON, J. LEWIS, 1, (22), 281
ALLISON, PATRICIA VAN BURGH, 1, (478)
Almond, bud failure in Jordanolo variety, 520
Alternaria **amaranthi** comb. nov., on Amaranthus paniculata in India, 668
  dianthi, carnation resistant to, 112
  porri, an incitent of onion blotch, 20
    f. dauci, on carrot, 215
  solani, effect of light on conidium production, 342
    effect of medium on sporulation and pathogenicity, 11
    inhibition point at various pH by helixin, 169
    physiologic races, 467
    spore germination, fungitoxicity of various chemotherapeutants, 127
    technique for observing spore germination on cleared leaves, 352
    on tomato, fungicide tests, 23
    vitamin nutrition, 657
  sp., part of transit rot complex of Vanda orchid flowers, 373
  tenuis, an incitant of onion blotch, 20
    on tomato fruit, 425
    var. sensu, longevity on stored grains, 13
  tenuissima, an incitant of onion blotch, 20
Amaranthus paniculatus, Alternaria blight in India, 668
American Phytopathological Society:
  abstracts of the 43rd annual meeting (Cincinnati), 1
  abstracts of the 44th annual meeting (Ithaca), 463
  proposed amendment to the constitution, 366
  report of 43rd annual meeting, 223
  reports and abstracts:
    Northeastern Division, 112
    Pacific Division, 511
    Potomac Division, 340
    Southern Division, 281
AMES, RALPH W., 289
Amino acids, in uredospores of various races of cereal rusts, 3
  synthesized by Ustilago zeae, 6
P-amino benozic acid, see Vitamins
Amylase inhibition, related to chemical constituents and fungitoxicity, 471
Anaerobic respiration, of glucose by fungi, effect of thiram on, 475
ANDERSON, AXEL L., 1, (52), 453
ANDERSON, CHRIS W., 110
ANDERSON, H. W., (13)
ANDERSON, RALPH L., 463
ANDES, J. O., 281
Anethum graveolens, see Dill
Anguillulina tritici (nematode), role in tundu bacterial disease of wheat, 291
Annulus tabaci see also Virus(es), tobacco ringspot —
  woody hosts of, 478
Antagonism between microorganisms, by Aspergillus clavatus, toward Bacillus subtilis, in sterile soil, 494
  by Bacillus polymyxa, toward Bacterium solanacearum, 4
  by Bacillus subtilis, toward a Rhizoctonia causing damping-off of sugar beet, 465
  by Bacillus sp. B6, toward Pythium spp. in soil, 618
  by Penicillium patulum, toward Pythium spp. in soil, 619
  by Streptomyces sp., toward Rhizocotonia solani, 473
  by Streptomyces sp. A67, toward Pythium spp. in soil, 618
  by Streptomyces venezuelae, toward Bacillus subtilis, 93
  by Trichoderma lignorum, toward Pythium spp. in soil, 618
  by Trichoderma viride toward Rhizoctonia solani, 465
  to Ceratostomella fimbriata by various organisms, 342
  to Pythium arrhenomanes, in soil, 12
  to Pythium arrhenomanes, by various microorganisms, 468
    tests of 5,638 bacterial isolates, 464
    tests of 5,218 fungal isolates, 469
    fungal isolates, 286
Anthracnose, peach, in Georgia, 343
  raspberry, control, 8
  tobacco, resistance to, in wild species of Nicotiana, 343
  of trees, 12
Antibiotics, see also Chemotherapeutants and Fungicides
    comparison of soil test with in vitro experiments on inhibition of Pythium root rot by actinomycetes, 284
    disappearance from the soil, 9
    effect on lesion production by plant viruses, 331
    recovery from soil, 295
    seed treatment, requirements for suitable control of damping-off, 613
  actidione, alfalfa damping-off, 616
    effect on mold count of processed black raspberries, 2
    inactivated in non-sterile soil, 9
    in the soil, 493
    phytotoxicity on cherry fruit, 14
    turf snow mold, 516
  aureomycin, adsorbed by clays in soil, 294

Antibiotics—*continued*
chloromycetin, activity in soil, 91
inactivated in non-sterile soil, 9
clavacin, inactivated in non-sterile soil, 9
in the soil, 493
endomycin, 506
fradicin, alfalfa damping-off, 616
gliotoxin, role in soil, 465
helixin, fungicidal activity, 13
production and purification, 506
Antibiotics
studies in relation to plant disease control, 168
helixin B, victoria blight of oat, 469
polymyxin, possible antagonism in control of bacterial wilt of tomato, 4
streptomycin, adsorbed and inactivted in soil, 9
bacterial soft rot of packaged spinach, 475
effect of cobalt on production of — by Streptomyces griseus, 123
streptothricin, adsorbed and inactivted in soil, 9
inhibition of tobacco necrosis and ring spot virus lesions, 332
terramycin, adsorbed by clays in soil, 294
inhibition of tobacco necrosis and ring spot virus lesions, 332
thiolutin, apple fire blight, 57
Fusarium wilt of tomato, 338
toximycin, from Bacillus subtilis, 20
Aphanomyces cladogamus, causing damping-off in peppers, 14
cochliodes, host range, 18
technique for producing zoospore inoculum, 18
euteiches, zoospores inoculum, 18
Aphelenchoides oryzae (nematode), laboratory culture, 21
nematocide tests, 463
seed treatment to control white tip of rice, 6
Aphis apii, vector for beet mosaic virus, 252
fabae, vector for alfalfa mosaic virus, 261
gossypii, vector for alfalfa mosaic virus, 261
medicaginis, vector for alfalfa mosaic virus, 261
Apium graveolens, see Celery
Apple, boron content of leaves and fruit, 464
effect of lime-sulfur and flotation sulfur on yield, 463
black rot, losses in Georgia, 288
cedar rust, inheritance of resistance, 19
dwarf fruit and decline, 4
fire blight, preliminary test for control with thiolutin, 57
russet, correlated with shrinkage in storage, 344
scab resistance, 11
Appresorial formation, in Phytophthora infestans, 16
Arachis hypogaea, see Peanut
Ark, Peter A., 320
Armstrong, G. M., 1, 255
Armstrong, Joanne K., (1), (255)
Arny, D. C., 222, (367), (469)
Asclepias syriaca, strawberry viruses in, 20
Ascochyta imperfecta, seed loss of alfalfa, 468
Ash, red, see Fraxinus pennsylvanica
Asparagus (A. officinalis),
Fusarium disease, on seedlings, 9
root-knot nematode, resistance, 6
rust, 13
Aspen, Hypoxylon canker, factors affecting, 463
Association of microörganisms, in flood fallowed banana soils, 476
Athow, Kirk, 660
Atkins, J. G., Jr., 1, (21), 282, 463
Aureogenus magnivena, wound tumor virus, 269
Autoradiographs, of fungi tagged with C^{14}, 431
Avocado, root rot, control by fungicide drench, 24
effect of irrigation, 35
Aycock, Robert, 428
Ayers, G. W., 25
Azab, Y. E., 282
Bacteria, see also under generic names
maintaining virulent inoculum by deep-freeze method, 13
six species, in apparently healthy pinto beans, 214
Bacterial soft rot of potato, role of suberization and periderm formation, 481
Bactericides, see under Fungicides
Bacterium solanacearum, controlled by antagonistic organism, 4
Bacillus polymyxa, antagonistic to Bacterium solanacearum, incitant of bacterial wilt of tomato, 4
inhibited by terramycin in soil, 295
subtilis, antagonistic toward a damping-off pathogen, 465
antibiotic toximycin from, 20
inhibited by Streptomyces aureofaciens in soil, 295
Bailey, D. L., 406
Bain, Douglas C., 497
Baines, R. C., 1, 77
Baker, Kenneth F., (478)
Baker, R. R., (21)
Bald, J. G., (478)
Baldacci, E., 38
Baldwin, M. M., (472)
Bardin, Roy, (573)
Bark canker of London plane, redbud and sweet gum, 16
Barley (Hordeum vulgare),
longevity in storage of several cereal seed fungi, 13
covered smut, effect of temperature and method of inoculation on post-emergence smutting, 117
loose smut, inheritance of resistance, 367
seed treatment with Spergon-SL, 476
mosaic virus, new, in Calif., 12
root rot, in Tennessee, 287
scald, field inoculation technique, 17
stem rust, on albino seedlings, 177
storage fungal infestations, 476
yellow dwarf virus, 15
Barnes, George L., 511, 512
Barnett, H. L., 1, 2, 57, 463, (476), 531
Barrat, J. G., (512)
Basidiobolus spp., from leaf mold, 341
Baxter, John W., 2
Bayberry, yellow virus, 17
Beale, Helen Purdy, (463)
Beale, J. H., 463
Bean (Phaseolus vulgaris),
alfalfa mosaic on, 344
anthracnose, seed treatment with Vancide 51, 1
ashy stem blight, 607
bacterial blight, chemotherapeutants, 72
charcoal rot, 607
fungus infection related to guttation, 520
halo blight, toxin production by pathogen, 475
Macrophomina leaf spot, 607
necrotic lesion strain of yellow bean mosaic virus, 24
powdery mildew, technique for fungicide screening test, 114
Rhizoctonia canker and blight, 607
rust, race 85 (new) in Maryland, 342
southern blight, 607
yellow mosaic virus (bean virus 2), in Montana, 101
white mold, fungicide tests, 477
broad — (Vicia faba), used for testing chemotherapeutants, 127
lima — (Phaseolus lunatus),
downy mildew, resistance, 43
root rot tolerance, 515
navy pea bean, seed treatment for anthracnose, 1
pinto, bacteria in apparently healthy seed, 214
effect of phosphate on inoculation with tobacco mosaic virus, 137
Beckman, C. H., 2, (13), 463
Beet (Beta vulgaris), see also Sugar beet
curly top virus, in potato, 516
damping-off, seed and soil borne infection, 520

Beet—*continued*
mosaic virus, aphid transmission study, 252
yellows, in Washington, 516
Bell, F. H., 340
Belonoliamus gracilis (nematode), associated with cotton wilt, 283
Beneke, E. S., 2, (24)
Bennett, C. W., 2, 535
Beraha, Louis, 2
Berbee, J. G., (2)
Berkeley, G. H., 2, 258
Beta vulgaris, see Beet and Sugar beet
Betula verrucosa, damping-off, affected by soil fertility and illumination, 502
Biochemical mutants, of Venturia inaequalis, 479
Biographical sketch, George James Wilds, Jr., 485
Herbert Spencer Jackson, 406
Oran Cecil Boyd, 405
Birch, see Betula
Bird, Julio, 3
Bitancourt, A. A., (12)
Black, L. M., 3, 269
Black measles (cause unknown) of grape, effect of dormant sodium arsenite spray, 158
Blephilia hirsuta, mint rust on, 2
Bloch, Robert, 483
Blodgett, E. C., 512
Bloom, James R., 3
Blueberry (Vaccinium spp.),
galls, bacterial, 88
incited by Nocardia vaccinii, 249
twig tip blight, strains of incitant, 513
Bobrov, Ruth Ann, 558
Boone, D. M., 479, (480)
Boosalis, M. B., 387
Boron, see Micronutrients
Borthwick, H. A., (341)
Botryodiplodia theobromae, on tung, 521
Botryosphaeria ribes, possible incitant of bark canker of London plane, redbud, and sweet gum, 16
on tung, 521
Botryosporium pulchrum, on cured tobacco, factors affecting development, 10
Botrytis cinerea, effect of actidione on conidia germination, 21
infection of bean leaves related to guttation, 520
tagged with C^{14}, 431
fabae, used with broad bean in testing chemotheraputants, 127
sp., on blueberry, strains, 513
part of transit rot complex of Vanda orchid flowers, 373
Bowman, D. R., (10)
Box elder, see Acer negundo
Boyce, John S., Jr., 282, (438)
Boyd, Oran Cecil, a biographical sketch, 405
Boyle, Lytton W., 282
Boynton, Damon, (464)
Brakke, M. K., (3), (269)
Brassica spp., resistance to black rot, 497
Braun, Alvin J., 3
Bremia lactuae, mode of penetration of lettuce, 513
Brennan, Eileen, (112)
Bretz, T. W., 3, 435
Bridgmon, G. H., 65
Brierley, Philip, 341
Brinkerhoff, L. A., 98
Bromfield, Kenneth R., 479
Brooks, A. N., (173)
Broyles, James W., 3, (479)
Brown, A. M., 479
Bruehl, George W., 4
Bruer, H. L., 282, (287)
Brussels sprouts, Fusarium wilt, 256
Burger, W. C., (19), (420)
Burrell, A. B., 463, 464
Cabbage (Brassica oleracea var. capitata),
black rot, seed transmission, 5, 316
Fusarium wilt, race 1, 1
physiologic races, 255
mosaic resistance, relation of air temperature and virus concentration, 83
Cairns, Eldon J., 4, 464
Calavan, E. C., 512
Calla, bacterial chalk rot, 320
Camellia, corky excrescence, control, 16
Camellia sasanqua, Exobasidium on, 147
Campbell, Leo, 512
Candida albicans, inhibition point at various pH by helixin, 169
zeylanoides, inhibition point at various pH by helixin, 169
Cantaloupe (Cucumis Melo),
powdery mildew, control, 335
virus on, 8
Capitophorus fragaefolii (aphid), vector for strawberry viruses, 20
Capsicum frutescens, see Pepper
Carbohydrates, synthesized by Ustilago zeae, 6
Carbon disulfide, possible role in the fungicidal action of sulfur, 14
Cardona, Canuto, (114)
Carnation (Dianthus caryophyllus),
bacterial wilt, inoculation studies, 342
Fusarium wilt, breeding for resistance, 112
symptomless carriers, 21
mosaic virus, inactivated by zinc ion, 418
properties and electron microscopy, 289
root transmission, 21
Carrot (Daucus carota),
alfalfa witches' broom virus in, 27
black root rot, 215
foliage blight, compared with Stemphylium disease, 215
root scab complex, 9
Stemphylium disease, 215
umbel blight, 217
Carthamus tinctoris, see Safflower
Cash, L. C., (277)
Castanea sativa (European chestnut), susceptible to oak wilt fungus, 3
Castanopsis sempervirens (bush chinquapin), susceptible to oak wilt fungus, 3
Cation, Donald, 4
Cauliflower (Brassica oleracea var. botrytis),
black rot, susceptibility of commercial varieties, 497
Fusarium wilt, 256
Celery (Apium graveolens),
adaxial crack stem, 603
awl nematode on, 175
late blight, control, 519
nematode stunt, 13
nematode stunt and chlorosis, 651
"red root" complex in Florida, nematodes as a factor, 131
sting nematode on, 173
Celino, Martin S., 4
Cellulase activity, of fruit rot fungi, 474
Cephalosporium acremonium, associated with corn stalk rot, 20
Ceratostomella, see also Endoconidiophora
fimbriata, antagonism toward, by Streptomyces sp., 342
erradicant fungicides, 7
inheritance of sex, 479
sulfur soil treatment, 590
ulmi, antagonism toward, by Streptomyces sp., 343
control by pruning, 113
Cercis canadensis (redbud), bark canker, 16
Cercospora sojina, dried grain inoculum, 469
inheritance of resistance to, in soybean, 660
on soybean seed, 568
Cercosporella albomaculans, on turnip, control with ferbam, 281

Cerdosporina kikuchii, isolation from soybean seed, 285
Cereals, see also specific crops and under Grasses
root rot, in Tennessee, 287
Xanthomonas streak, 387
yellow dwarf virus, host range, 518
CETAS, ROBERT C., 464
Chalara quercina, see also Endoconidiophora fagacearum and Oak wilt
asigerous stage, 435
crossing of various isolates, 463
diploidization, 537
factors affecting growth and sporulation in culture, 2
growth in liquid culture, nutrition, 463
host range, five new woody hosts, 3
liquid culture for rapid identification, 57
longevity at various temperatures and relative humidities, 470
macroscopic growth in nature, 6
mycelal mat production on oak in Pennsylvania, 681
nutritional requirements, 2, 288, 463
perithecial stage, in culture, 3
role in dissemination, 691
plugging of xylem vessels associated with oak wilt, 2
potential source of perithecia in nature, 531
quick test for, 1
spore liberation, 537
from natural reservoirs, 476
CHAMBERLAIN, D. W., 4, 299
CHAPLIN, J. F., (15), (286)
CHAPMAN, R. A., 72
Chemotherapeutants,
1182 (4-chloro-3,5-dimethyl phenoxyethanol), tobacco mosaic virus, 465
alkyl dimethylethylbenzylammonium chloride, oak wilt, 11
p-aminobenzoic acid and p-aminobenzene sulfonamide, broad bean chocolate-spot, 129
2-(n-amyl)pyridine, comparison of fungitoxic and chemotherapeutic activity, 6
auramine, bean blight, 73
azo dyes, broad bean chocolate-spot, 128
benzoic acid, bean blight, 73
benzoyl methyl thiocyanate, bean blight, 73
butoxypolypropylene glycol, bean blight, 73
cadmium succinate, oak wilt, 11
calcium chloride, bean blight, 73
calcium sulfamate, oak wilt, 11
2-carboxymethylmercaptobenzothiazole salts, for various diseases, 7
sodium salt, comparison of fungitoxic and chemotherapeutic activity, 6
4-chloro-3,5-dimethylphenoxyethanol, comparison of fungitoxic and chemotherapeutic activity, 6
complex metallic dinicotine salicylates, 129
crotonic acid, bean blight, 73
cupric ion, tomato Fusarium wilt, 465
cyclopentenyl butyldithiocarbamate, bean blight, 73
dehydranone, bean blight, 73
a,a'dipyridyl, tomato Fusarium wilt, 465
dyes, bean blight, 75
2-(1-ethylamyl)-2-imidazoline-1-polyglycol, bean blight, 73
ethylene urea, bean blight, 73
HD 3(n-octadecyltrimethylammoniumpentachlorophenate), root injury reducing Fusarium wilt severity in tomato, 312
hydroxyquinoline derivatives, broad bean chocolate-spot, 128
8-hydroxy quinoline benzoate, oak wilt, 11
8-hydroxy quinoline sulfate, oak wilt, 11
lauryl isoquinolinium bromide, bean blight, 74
malachite green, oak wilt, 11
mercury compounds, bean blight, 75
miscellaneous compounds, bean blight, 75
2-(4-morpholinyl)-ethylphenylketone, bean blight, 73
Chemotherapeutants—*continued*
nabam (disodium ethylene bisdithiocarbamate), oak wilt, 11
n-(4-nitrophenyl)-3,4-dichlorobenzene sulfonamide, bean blight, 73
n-octadecyltrimethylammoniumbromide, bean blight, 73
n-octadecyltrimethylammonium pentachlorophenate, comparison of fungitoxic and chemotherapeutic activity, 6
root injury reducing Fusarium wilt severity in tomato, 312
oxyquinoline benzoate, comparison of fungitoxic and chemotherapeutic actiivty, 6
o-phenanthrolene, tomato Fusarium wilt, 465
phenols, bean blight, 74
phenylmercuritriethanolammoniumlactate, oak wilt, 11
potassium permanganate, bean blight, 73
protocatechuic acid, bean blight, 73
quaternary ammonium compounds, bean blight, 75
quinolinol derivatives, bean blight, 74
8-quinolinol phosphate, bean blight, 73
8-quinolinol salicylate, bean blight, 73
8-quinolinol sulfate, stock Rhizoctonia root rot, 476
salicylates, bean blight, 74
salicylic acid, broad bean chocolate-spot, 128
bean blight, 73
sodium dimethyldithiocarbamate, oak wilt, 11
+ sodium 2-mercaptobenzothiazole, oak wilt, 11
sodium 2-mercaptobenzothiazole, oak wilt, 11
sodium trichlorophenate, oak wilt, 11
sorbic acid, bean blight, 73
sulfonamides, bean blight, 75
Tergitol-4, bean blight, 73
ureas and thioureas, broad bean chocolate-spot, 130
zinc sulfate, bean blight, 74
Chemotherapy:
activity independent of fungitoxicity, 6
alteration of disease resistance with chemicals, 563
behavior of groups of reported chemotherapeutants, 127
foliage spray applications for control of Dutch elm disease, 7
oak wilt, test of 37 organic chemicals, 11
plant regulators, effect on Fusarium wilt susceptibility of tomato, 465
postulated chelation of Fusarium toxin, 465
tomato Fusarium wilt, with thiolutin, 338
root injury as a factor in assessment, 113, 311
Chenopodium urbicum, local lesion host for lettuce mosaic virus, 478
CHEO, PEN-CHING, 4, (16), (301), 306, 377
CHEREWICK, W. J., (472)
Cherry (Prunus avium and P. cerasus),
crown gall, incipient in seedlings, 520
leaf spot, fungicide tests, 14
little cherry virus disease, grafting experiments, 477
mora virus disease, 347
necrotic ringspot virus strains, 470
ringspot virus, effect on growth, 470
seed transmission, 4
separation, 517
storage rots, controls, 24
western X disease, symptoms on sweet cherry, 519
western X little cherry virus, effect on seed, 515
yellows, seed transmission, 4
separation, 517
Chestnut, European, see Castanea sativa
blight, epiphytotic in Italy, 38
Chickpea (cicer arietinum),
Mycosphaerella blight, basis of resistance, 422
CHILDS, J. F. L., 265
CHILTON, JOHN E., 5
CHILTON, S. J. P., (282)
CHRISTENSEN, C. M., (476)
CHRISTIANSEN, D. W., (211)
CHRISTIE, J. R., 173, 483

Chrysanthemum, stunt, increase of symptoms under high intensity light, 341
Cicer arietinum, see Chickpea
Circulifer tenellus (leafhopper), inducing vein clearing of sugar beet, 535
Citrus limonia, see Lemon
sinensis, see Orange
cachexia disease of, 265
tristeza, relation to cachexia disease, 267
grafting experiments, 280
xyloporosis, relation to cachexia disease, 267
Citrus-root nematode, on olive, 77
Clarke, O. F., (1)
Claviceps spp., inoculation and culture, 513
Clayton, E. E., 5, 482
Climatic disease, defined, 283
Clostridium carbonei, in apparently healthy pinto beans, 214
Clover:
alsike (Trifolium hybridum),
rootlet rot, 514
Volutella sp. parasitic on, 5
Kaimi (Desmodium canum),
new virus disease of, in Hawaii, 517
Ladino (Trifolium repens),
Sclerotium rolfsii on, 1
red (Trifolium pratense),
legume virus reservoir, 467
Pythium spp., comparison of pathogenicity, 10, 245
root rot, 466
vein mosaic, crystalline inclusions, 518
Volutella sp. on, 5
Cobalt, see Micronutrients
Cochran, L. C., (443), 512
Cochrane, Vincent W., 5
Coffee, spot anthracnose, 12
Cohen, Morris, 464,(474), 512, (519)
Colburn, R. W., (25)
Collards, Fusarium wilt, 256
Colletotrichum falcatum, tagged with C^{14}, 431
lagenarium, factors affecting spore germination and pathogenicity, 478
hydrolysis of pectin, 474
in tomato fruit, 18
lindemuthianum, infection of bean leaves related to guttation, 520
seed treatment of navy pea bean, 1
lini, physiologic specialization, 18
phomoides, effects of tribasic copper sulfate and ziram on cultures, 470
growth inhibition by solanine, 1
hydrolysis of pectin, 474
on tomato, fungicide tests, 114
pathogenic variation, 18
resistance to, in tomato, 113
sativum sp. nov., on vetch, 670
sp., on tobacco, resistance to anthracnose among Nicotiana spp., 343
trifolii, alfalfa seed treatment, 22
viciae, on vetch, 670
villosum, on vetch, 670
Comegys, W. R., (464)
Complement fixation for differentiating strains of tobacco mosaic virus, 16
Conidial germination, Albugo occidentalis, factors affecting, 17, 449
Conidial matrix, effect on spore germination and pathogenicity of Colletotrichum lagenarium, 478
Conidiobolus brefeldianus, from leaf mold, 341
minor, from leaf mold, 341
spp., isolation technique, 341
utriculosus, 341
Conidium production, see Sporulation
Conifers, Rhizoctonia damping-off, 464
Coniothyrium fuckelii, copper nutrition, 468
Connell, Thomas D., 464
Conover, Robert A., (197)
Cook, A. A., 5, 162, 316
Coons, G. H., 341, 482
Cooper, D. C., 25
Cooper, W. E., 282
Cooper, see Micronutrients
Corium **zeae** n. sp., maize leaf-fleck virus, 688
Cormack, M. W., 5, (510)
Corn (Zea mays),
cold-testing, 467
emergence related to injury and drying of seed, 221
seed germination test technique, 11
seed treatment, varietal differences, 284
brown spot, evaluation of inoculation techniques, 284
crazy top, 675
Diplodia seedling blight, varietal resistance, 473
stalk rot, 476
varietal resistance, 473
ear rot, fungal infections of apparently healthy seed, 286
leaf-fleck virus disease, 683
Pythium root rot, 12
inhibited by actinomycete, 284
control by antagonistic microorganisms, 468
smut, partial vacuum inoculation, 17
stalk rot, following corn borer, 20
sting nematode, 173
Cortitium vagum, variation in culture, 473
Corynebacterium fimi, in apparently healthy pinto beans, 214
flaccumfaciens, in apparently healthy pinto beans, 214
helvolum, in apparently healthy pinto beans, 214
insidiosum, maintenance of virulent inoculum by deep-freeze method, 13
tritici, on wheat, 291
Corynespora cassiicola, dried grain inoculum, 469
Costa, A. S., 231, 280, 396
Cotton (Gossypium spp.),
anthracnose of seedlings, seed treatment, 470
bacterial blight, frequency of varietal resistance, 98
boll rot, fungicide tests to control, 285
Fusarium wilt, inheritance of resistance, 287
sting nematode a factor in disease severity, 283
tight lock, fungicide tests to control, 285
Verticillium wilt, seedling inoculation technique, 288
Cowpea (Vigna sinensis),
assay host for cucumber virus 1, 328
cucumber mosaic, strain of cowpea susceptible to systemic infection, 442
Fusarium wilt, varietal resistance, 283
mutation rate of tobacco necrosis virus on, 156
Cox, C. E., (11), (470), (475)
Cox, R. S., 118, 464, (468)
Crall, J. M., 5
Cralley, E. M., 6
Crittenden, H. W., 6
Cronartium cerebrum, compared with Peridermium appalachianum, 116
coleosporioides, compared with Peridermium appalachianum, 116
comptoniae, compared with Peridermium appalachianum, 115
fusiforme, compared with Peridermium appalachianum, 116
ribicola, compared with Peridermian appalachianum, 116
pruning of diseased pines, 475
Crop rotation, for control of golden nematode, 345
Crowdy, S. H., 127
Crowe, A. D. (464)
Crowley, D. C., (513)
Crown gall, growth rate of tissue in vitro, 514
Cucumber (Cucumis sativus),
angular leaf spot, 105
mosaic, virus inhibitor in resistant varieties, 349
stem and fruit rot, 14

Cucumber—*continued*
virus on, 8
wild, virus on, 8
Cucumis melo, see Cantaloupe
Cucumis sativus, see Cucumber
Cucurbits: seven viruses on, in California, 8
Cuerna yuccae (leafhopper), vector of Pierce's disease virus, 533
CULVER, ANDREW J., JR., 513
CUMMINGS, R. H., 513
CUMMINGS, GEORGE B., (10), (115)
Cunila origanoides, mint rust on, 2
CURL, E. A., 6
Curvularia lunata, effect of light on conidium production, 342
Cuscuta campestris, transmission of alfalfa witches' broom virus, 27
transmission of bayberry yellows virus, 17
grovonii, transmission of strawberry viruses 1 and 2, 20
subinclusa, transmission of peach X disease virus, 475
transmission of strawberry viruses 1 and 2, 20
CUTTER, VICTOR M., JR., 479
Cytology, of Helminthosporium carbonum, 480

Dactylis aschersoniana, purple leaf spot, 653
glomerata, purple leaf spot, 653
DAINES, ROBERT H., 112
Dalbulus maidis (leafhopper), study on specific transmission of viruses, 663
Damping-off, beet, relative importance of seed and soil borne infection, 520
conifer seedlings, effect of humus, 202
seed treatment of pea and cotton, 470
sugar beet, control, 465
tree seedlings, affected by soil fertility and illumination, 501
vegetable seedlings, caused by Aphanomyces cladogamus, 14
DANA, B. F., (477)
DARLEY, ELLIS F., 547
Daucus Carota, see Carrot
DAVIES, MARY-ELIZABETH, (127)
DAVIS, DAVID, 6, (7), 465, 563
DECKER, PHARES, 283
Defense reactions of plants to toxins, 483
Deficiency diseases, see Mineral element deficiency
DELWICHE, C. C., (519)
DEMAREE, J. B., 88, 249
DESJARDINS, P. R., (343)
Desmodium canum, see Clover, Kaimi
Deuteron bombardment, effect on pathogenicity and serology of viruses, 472
DEVAY, J. E., 6, (17)
Developmental races, defined, 645
DEWOLFE, T. A., (512)
DEZEEUW, DONALD J., 52
DIACHUN, STEPHEN, 6
Dianthus barbatus, see Sweet William
Dianthus caryophyllus, see Carnation
Diaporthe phaseolorum batatatis, on soybean, inoculation method, 5
Dichanthium annulatum, new Sclerospora on, 596
DICK, J. B., (287)
DICKSON, J. G., (10), (245), 465
DIENER, T. O., (512)
DIENER, U. L., 7
DIETZ, SHERL M., (513)
Dill (Anethum graveolens), Fusarium root rot and wilt, 1, 152
nematode on, in Conn., 13
DILLER, J. D., 341
Dimethylamine, possible role in the fungicidal action of sulfur, 14
DIMOND, A. E., 7, (22), 72, (113), (311), 465, (472), (563), (599)
Diplodia spp., infecting apparently healthy corn seed, 286
zeae, associated with corn stalk rot, 20
correlation of growth rate on plant juice extracts with resistance, 476
correlation of varietal resistance in corn to seedling blight and stalk rot, 473
Disease development, white rust of spinach, factors affecting, 451
Disease resistance, affected by root injury, 311
alteration of, with chemicals, 563
multiple, in oats, breeding, 482
in potato, breeding, 483
in strawberry, 468
in sugar beet, breeding, 482
in tobacco, breeding program summary, 482
in Wisconsin tobacco, 12
in tomato, 197
of apple to scab, use of tetraploids, 11
of carnation, 112
of chickpea to Mycosphaerella blight, basis of resistance, 422
of corn to Diplodia stalk rot, correlation with growth of pathogen on plant extracts, 476
varietal correlation to Diplodia seedling and stalk rot, 473
of cucumbers, to mosaic virus, 349
of lima bean, to root rot, 515
of potato to late blight, problems in breeding, 277
to Verticillium wilt correlated with lateness of variety, 26
of safflower, to root rot, 219
of spinach, to cucumber virus 1, 304
of sweet potato, to internal cork, 287
of tobacco, testing methods for evaluating, 5
to black shank, 288
to wildfire, 12
of fluecured tobacco varieties, 284
of Wisconsin tobacco to mosaic virus, 8
of tomato, to southern bacterial wilt, inoculation methods used to test, 628
throughout plant, to Fusarium wilt, 474
of tomato fruit, constitutents for resistance to anthracnose, 18
Disease susceptibility, of cowpea strain to systemic infection by cucumber virus 1, 442
Ditylenchus nematode, anabiotic survival, 464
DOBIE, NORMAN D., 513, 693
Dodder, see Cuscuta spp.
Dolichodorus heterocephalus (nematode), factor in "red root" complex on celery in Florida, 131
DOOLITTLE, S. P., 7
DORSEY, C. K., (476), (537)
Dosage-response data, differentiation between inherent fungitoxicity and permeation, 457
Draeculacephala californica (leafhopper), vector of Pierce's disease virus, 533
crassicornis, vctor of Pierce's disease virus, 533
noveboracensis, vector of Pierce's disease virus, 533
DRECHSLER, CHARLES, 341
DRIVER, CHARLES H., 479
DUNEGAN, JOHN C., 341, (343)
DUNLAP, V. C., (476)
DUNLEAVY, JOHN M., 465

Echinochloa crus-galli, Ephelis oryzae on, 634
Eggplant, Verticillium wilt, chemotherapy, 7
EGLITIS, MAKSIS, 513
EICHENMULLER, J. J., 7
EIDE, CARL J., 465, (481)
Electrophoresis, used in quantitative study of competition between two strains of tobacco mosaic virus, 464, 474, 519
Eleocharis dulcia (Chinese water chestnut), awl nematode on, 114
ELLISON, J. HOWARD, 25

Elm, Dutch — disease, control by pruning, 113
chemotherapeutant foliage spray, 7
tomato rnig spot virus strain on, 477
EMGE, R. G., 133
Endoconidiophora, see also Ceratostomella
fagacearum sp. n., asigerous stage of Chalara quercina, 435
sexuality, 438
fimbriata f. platani, destructiveness on planetree, 236
Endothia parasitica, perithecia in culture, 39
ENGLISH, HARLEY, 513
Environment, effect on concentration of cucumber virus 1 in spinach, 4
effect on lemon sieve tube necrosis, 18
Environmental races, defined, 645
Enzyme activity, extracellular, method for study with C^{14} labeled fungus material, 23
Enzymes, fermentive, inhibition by chloranil, 11
Ephelia oryzae, on grasses in India, 634
Eradication, by pruning, of Dutch elm blight in individual trees, 113
Erodium spp., red leaf virus on, 110
ERWIN, DONALD C., 32, 513
Erwinia amylovora, rapid inoculation of pear seedlings, 341
f. rubi, on raspberry, 114
aroideae (?), on calla, 321
caratovora (?), on calla, 321
Erysiphe cichoracearum, on cantaloupe, 335
graminis var. tritici, comparison of reaction on wheats, 8
Escarole, bacterial soft rot, 112
Ethylene diamine, possible role in the fungicidal action of sulfur, 14
EVANS, ELFED, 465
EVANS, MARSHALL, 7
Exobasidium camelliae var. gracilis, 147

FASSULIOTIS, GEORGE, 466
FEAZELL, GEORGE D., 7
FEDER, WILLIAM A., 373, 466
FEICHTMEIR, EDMUND F., 200
FELDMESSER, J., (193), (466), 466
FELIX, E. L., 283
FERGUS, C. L., (681)
Fermentation, effect of chloranil on fermentive enzyme systems of fungi, 11
FERRELL, WILLIAM K., (515)
Fig, Phomopsis canker, 513
Filaree, red leaf virus on, studies, 110
FINK, GEORGE, (98)
Fir, Douglas, factors affecting decay rate, 518
FISCHER, GEORGE W., 479
FITZPATRICK, R. E., (516)
Flax, rust, disease development, 204
technique for inoculation with Fusarium, 515
virulence of Colletotrichum lini, 18
FLOCK, R. A., (533)
Flood fallow of banana soils, soil flora, 476
Fluorine, injury to vegetation, 112
Foliar sprays, see Nutrition, hosts and suspects
Folic acid, see Vitamins
FOLSOM, DONALD, 112, (114)
Fomes pini, factors affecting decay of fir by, 518
Food processing, mold count in black raspberries following various sprays, 2
FOSTER, H. H., 7
Fragaria chiloensis, see Strawberry
vesca, indicator for strawberry viruses 1 and 2, 20
Fraxinus pennsylvanica, tobacco ringspot virus on, 478
FRAZIER, N. W., (533)
FREDERICK, LAFAYETTE, 514
FREITAG, J. H., 8, 533
FRENCH, R. G., (6)
FRIEDMAN, B. A., 112
Frost injury, blister shake of yellow poplar, 21
FULTON, J. P., 8
FULTON, ROBERT H., 8
FULTON, R. W., 8, (12), 156, (331), 413
Fumigation, of potato handling equipment, 489
Fungicides, general:
absorption (selective), studied with radioactive isotopes, 478
accumulation of fungicide by spores, 470, 471
action of breakdown of dithiocarbamates, 477
amylase inhibition related to fungitoxicity, 471
anaerobic breakdown of glucose in fungi affected by thiram, 475
bioassay of amount of fungicide on commercially treated oat seeds, 222
concentrated sprays, for control of black rot and downy mildew on grapes, 3
constitution of quinonoid and benzenoid compounds related to fungitoxicity, 471
dosage, absorption of fungicides by spores, 470
dry and slurry seed treatment comparisons, 52
fungitoxicity independent of chemotherapeutic activity, 6
laboratory ED 50 related to field performance, 113
mold count in processed black raspberries, effect of various fungicidal sprays, 2
penetration, related to water- lipid-solubility, 17
permeation, related to lipid solubility, 457
prediction of field performance, 477
slurry preparations compared with wettable powders, 23
spreader-stickers, CP-5, with cotton sprays, 285
Triton, 8
Tween 20, for preharvest treatment of spinach, 475
tests using half-tree plots, 114, 353
toxicity, of amorphous droplets compared to crystalline form of sulfur, 200
studied with radioactive elements, 478
vapor pressure of amorphous droplets compared to crystalline form of sulfur, 200
volatile chemicals for reducing fruit rots, 19
wash-off curve related to field performance, 113
Fungicides (specific compounds), see also Chemotherapeutants:
actidione, see also Antibiotics, actidione
cherry leaf spot, 14
effect on conidial germination, 21
tests for control of small fruit storage rots, 24
turf diseases, 22
Agrox, corn seed, 284
potato seed piece treatment, 26
Arasan, alfalfa seed treatment, 22
asparagus Fusarium seedling disease, 9
cereal smuts, 10
cereal Victoria blight, 10
comparison of dry and slurry application, 52
corn seed, 284
pea seed protectant, 10
potato seed piece treatment, 26
safflower rust, seed treatment, 109
soybean, effect on nodule bacteria, 19
sugar beet, seedling diseases, application rates, 13
Arasan SF, pea seed protectant, 10
benzenoid compounds, relation of fungitoxicity to amylase inhibition, 471
Bioquin, effect on fungus growth, 471
Bioquin 1 (copper 8 quinolinolate),
effect on fungus growth, 471
erradicant for Ceratostomella fimbriata, 7
Bisphenol A, peach fruit rot, 342
bordeaux, apple black rot, phytotoxicity, 288
effect on fungus growth, 471
lemon brown rot, 512
Cadminate (organic cadmium compound), turf diseases, 22
turf snow mold, 516
calcium hypochlorite, for post-harvest control of peach brown rot, 7
Calo-clor, turf diseases, 22, 516
Calocure, turf snow mold, 516

Fungicides—*continued*

carbon disulfide, possible role in the action of sulfur, 14
C & C 224, potato seed piece treatment, 26
C & C 1025, turf snow mold, 516
Ceresan, bean charcoal rot, 607
Ceresan M, bioassay of treated oat seed, 222
cereal smuts, 10
comparison of dry and slurry application, 52
safflower rust, seed treatment, 109
snow mold of wheat, 475
Victoria blight on cereals, 10
Ceresan, New Improved, cereal smuts, 10
gladiolus, 518
Victoria blight on cereals, 10
chloranil (tetrachloro-para-benzoquinone), 288
alfalfa seed treatment, 22
cereal smuts, 10
comparison of dry and slurry application, 52
effect on fermentive enzyme systems in fungi, 11
loose smut of barley, 476
pea seed protectant, 10
potato seed piece treatment, 26
soybean, effect on nodule bacteria, 19
turf snow mold, 516
Victoria blight on cereals, 10
chlorinated phenols, potato scurf, 512
chloropicrin, in steam for storage-house fumigation, 513 693
Clorox, peach fruit rot, 342
Cop-O-Zink, white mold of bean, 477
Copper A, lemon brown rot, 512
peach fruit rot, 342
copper carbonate, cereal smuts, 10
Crag 341, raspberry anthracnose, 23
peach fruit rot, 342
Crag 531, peach fruit rot, 342
turf diseases, 22
turf snow mold, 516
Crag 640, lemon brown rot, 512
Crag 658, peach fruit rot, 342
Crag 1025, turf diseases, 22
Crag 5379, peach fruit rot, 342
cupric chloride, effect on fungus growth, 471
cupric sulfate, effect on fungus growth, 471
peach bacterial spot, dormant spray, 14
cuprous oxide, effect on fungus growth, 471
DHA (dehydroacetic acid), Vanda orchid flower rot, 373
DHA-S (sodium salt of DHA), peach brown rot, 19
peach fruit rot, 342
dimethylamine, possible role in the action of sulfur, 14
2,4-dinitrofluorobenzene, pea seed, 470
Dithane D-14, see also nabam,
plus ferric sulfate, for post-harvest control of peach brown rot, 7
Dithane Z-78, see zineb
2-dodecyl-2-imidazoline, lipid- water-solubility, 17
Dow 9B, alfalfa seed treatment, 22
pea seed protectant, 10
safflower rust, seed treatment, 109
Dowcide A, Vanda orchid flower rot, 373
Dowcide G, soil application for control of Phytophthora cinnamomi, 24
ethylene bisdithiocarbamtes, for post-harvest control of peach brown rot, 7
ethylene diamine, possible role in action of sulfur, 14
ferbam (ferric dimethyl dithiocarbamate),
apple black rot, 288
cherry leaf spot, 14
effect on fungus growth, 471
effect on mold count of processed black raspberries, 2
raspberry anthracnose, 23
raspberry anthracnose and spur blight, 8
turnip-green leaf spot, 281
plus Phygon, raspberry anthracnose, 23
formaldehyde, onion smut, 15
phytotoxic residue in flats, 171

Fungicides—*continued*

General Chemical 1189, for post-harvest control of peach brown rot, 7
Glyoxalidine (2-heptadecyl-2-imidazoline),
interaction with fungus spores, 15
lipid- water-solubility study, 17
true dosage at ED 50, 470
cherry leaf spot, 14
hydrogen sulfide, possible role in action of sulfur, 14
2-imidiazoline derivatives, fungitoxicity related to lipid solublity, 458
Iscothan (dinitro capryl phenyl crotonate),
cantaloupe powdery mildew, 335
peach fruit rot, 342
KF 467, pea seed protectant, 10
treatment of various vegetable and cereal seeds, 11
lime-sulfur, apple trees, cumulative effect, 463
lysis of rust spore germ tubes, 70
peach fruit rot, 342
manganese ethylene bis dithiocarbamate, cherry leaf spot, 14
onion blast and mildew, 15
potato seed piece treatment, 26
raspberry anthracnose, 23
slurry preparation compared with wettable powders, 23
tomato anthracnose and gray leaf spot, 114
M. E. M. A., corn seed, 284
mercuric chloride, cereal seed treatment, 471
gladiolus, 518
Mergamma, corn seed, 284
nabam, onion blast and mildew, 15, 212
soil application for control of Phytophthora cinnamomi, 24
nabam-zinc, cherry leaf spot, 14
Natriphene, Vanda orchid flower rot, 373
nitrophenol carbonate, peach fruit rot, 342
4-nitrosopyrazole derivatives, fungitoxicity related to lipid solubility, 459
Orthocide 406 (n-trichloromethylthio tetrahydrophthalimide),
cherry leaf spot, 14
cotton boll rot, 285
grape storage decay, 514
lemon brown rot, 512
onion smut, 15
peach brown rot, 7
peach fruit rot, 342
potato seed piece treatment, 26
raspberry anthracnose, 23
turf snow mold, 516
Panogen, cereal smuts, 10
safflower rust, seed treatment, 109
Victoria blight on cereals, 10
Parathion, for post-harvest control of peach brown rot, 7
Parzate, onion blast and mildew, 15
potato seed piece treatment, 26
safflower rust, seed treatment, 109
phenols, oxidized to quinones by fungus, 473
Phygon (2,3-dichloro-1,4-naphthoquinone)
alfalfa seed treatment, 22
comparison of dry and slurry application, 52
pea seed protectant, 10
potato seed piece treatment, 26
safflower rust, seed treatment, 109
stem rust of wheat, 465
PMAS, turf snow mold, 516
propylene glycol, peach fruit rot, 342
Puratized, effect on fungus growth, 471
inactivation by clays, 513
Puraturf, turf snow mold, 516
Puraturf GG, turf snow mold, 516
Puraturf 177, turf snow mold, 516
8-quinolinol sulfamate, peach fruit rot, 342
quinonoid compounds, relation of fungitoxicity to amylase inhibition, 471

Fungicides—*continued*
Rohm & Haas (CR-2379, for post-harvest control of peach brown rot, 7
Santobrite (sodium pentachlorophenate), erradicant for Ceratostomella fimbriata, 7
Seedox, peach fruit rot, 342
safflower rust, seed treatment, 109
Semesan bel, potato seed piece treatment, 26
Semesan Jr., corn seed, 284
sodium dialkyldithiocarbamates, fungicidal action, 472
sodium salt of dehydroacetic acid, tests for control of small fruit storage rots, 24
Sound Delivery, tests for control of small fruit storage rots, 24
Special Semesan (mixture of hydroxymercurichlorophenol and hydroxymercuricresol) turf diseases, 22, 516
Spergon, see chloranil
sulfur, flotation, apple trees, cumulative effects, 463
interaction with fungus spores, 15
mode of action, 14
peach brown rot, 7
peach fruit rot, 342
wettable, peach brown rot control, 19
Tact-C-Lect, turf snow mold, 516
turf diseases, 22
Tersan, onion smut, 15
turf snow mold, 516
tetrachloroethylene, fruit rots, 19
tetrachloro-para-benzoquinone, see chloranil, 288
thiram (tetramethyl thiuram disulfide), see also Arasan,
effect on anaerobic breakdown of glucose by fungi, 475
onion smut, 15, 469
pepper seedlings, damping-off, 14
potato seed pieces, 25
turf diseases, 22
tribasic copper sulfate, celery late blight, 519
cotton boll rot, 285
effect on Colletotrichum phomoides, 470
tomato anthracnose and gray leaf spot, 114
cherry leaf spot, 14
trichloroethylene, fruit rots, 19
triethylene glycol, peach fruit rot, 342
Vancide 51 (sodium salts of dimethyl dithiocarbamic acid and of 2-mercaptobenothiazole),
bean anthracnose in navy pea bean seed, 1
cereal smuts, 10
onion smut, 15
potato seed piece treatment, 26
soil application for control of Phytophthora cinnamomi, 24
sweet potato black rot, 7
turf diseases, 22
Victoria blight on cereals, 10
Zac (zinc dimethyl dithithiocarbamate-cyclohexylamine), slurry preparation compared with wettable powders, 23
zinc-copper lime, lemon brown rot, 512
zinc oxide, potato seed piece treatment, 26
zineb (zinc ethylene bisdithiocarbamate),
effect on growth and zinc content of tomato plants, 133
cotton boll rot, 285
onion blast and mildew, 15, 212
potato seed pieces, 25
tomato anthracnose and gray leaf spot, 114
ziram (zinc dimethyl dithiocarbamate),
celery late blight, 519
effect on Colletotrichum phomoides, 470
potato seed piece treatment, 26
slurry preparation compared with wettable powders, 23
tomato anthracnose and gray leaf spot, 114
white mold of bean, 477
ziram and zinc mercaptobenzothiazole, slurry preparation compared with wettable powders, 23
Fungitoxicity, contrasted with chemotherapeutic activity, 563
related to lipid-solubility, 17, 457
Fungitoxicity—*continued*
relative effect of phenols and quinoes on black and hyaline fungi, 473
sulfur, compounds concerned in mode of action, 14
Fusarium acuminatum, an incitant of alfalfa crown bud rot, 510
avenaceum, an incitant of alfalfa crown bud rot, 510
bulbigenum var. niveum, virulent strain on Iroquois muskmelon, 465
conglutinans, physiologic races, 255
physiologic races of, 1
dianthia, breeding carnation resistant to, 112
lycopersici, effect on phosphorus, distribution in tomato, 22
on tomato, effect of root injury, 311
on tomato, reduced disease severity related to root injury, 113
physiology and pigment production, 119
moniliforme, associated with corn stalk rot, 20
infecting apparently healthy corn seed, 286
nivale, on turf, fungicide tests, 516
oxysporum, on asparagus seedlings, 9
on cabbage and radish, 1
f. batatas, antagonism toward, by Streptomyces sp., 343
sulfur soil treatment, 590
f. dianthi, symptomless carriers, 21
f. gladioli, penetration of corms prevented by wound periderm, 342
f. lini, technique for flax inoculation, 515
f. lycopersici disease index on tomato increased by foliar sprays, 3
effect of plant regulators on wilt severity in tomato, 465
inhibited by thiolutin, 338
on tomato, chemotherapy, 465
possible use of ionizing radiation for disease therapy, 559
wilting mechanism, 18
f. narcissi, effect of temperature on growth, 407
f. perniciosum, Toole Race 1, and Toole Race 2, 694
f. vasinfectum, inheritance of resistance to—in cotton, 287
roseum, an incitant of root and rhizome rot of peppermint, 514
solani f. phaseole, on lima bean, tolerance to, 515
f. pisi, effect of chloranil on fermentive enzyme systems, 11
sp., associated with nematodes on celery, 652
on grains, 468
on orchid, 517
on peppermint, 514
spp., specificity of host-pathogen, 1
vasinfectum, physiology and pigment production, 119
Futrell, Maurice C., 8

Gainor, C., 8
Gallegly, M. E., (16), 461, 466
Galls, blueberry, bacterial, 88
growth rate in vitro of bacteria-free crown gall tissue, 514
on cherry seedlings, 520
produced by morphological varients of Agrobacterium tumefaciens, 8
production of indole acetic acid by Ustilago zeae, 24
root, incited on tomato by golden nematode, 466
Garren, K. H., (607)
Gasiorkiewicz, E. C., 9, (25), 183
Gattani, M. L., 70
Gaylussacia baccata, possible host of blueberry gall actinomycete, 249
Genetic factors for resistance: carrot genotypes susceptible to root scab complex, 9
in apple, to scab, 11
in apple, to cedar rust, 19
in lima bean to downy mildew, 43
in Nicotiana to tobacco mosaic virus, 40

Genetic factors—*continued*
in onion to downy mildew, 22
in peppers, morphology of stylar region of fruit, 7
in potato to late blight, 277
in potato hybrids to late blight, 26
in soybean to frog-eye leaf spot, 660
in spring barley to loose smut, 367
in sugar beets to Cercospora leafspot, 344
in Wisconsin tobacco to mosaic, 8
Genetics of microörganisms: Ceratostomella fimbriata, inheritance of sex, 479
Chalara quercina, crossing of various isolates, 463
Phytophthora infestans, races, 26
Pyrenochaeta terrestris, induced mutation by nitrogen mustard, 183
Ustilago zeae, sporidial mutations, 480
Venturia inaequalis, gene pairs conditioning pathogenicity, 480
induced biochemical mutants, 479
GERDEMANN, J. W., 466
Germination inhibitor, of seeds from wood of Prunus spp., 285
Gibberella zeae, associated with corn stalk rot, 20
GIBSON, ROY E., (4)
GIDDINGS, N. J., 514, (516)
GILPATRICK, J. D., (417)
Gladiolus, bean virus 2 on, 65
corm rot, role of wound periderm, 342
cucumber virus 1 on, 65
effect of mercurial fungicides, 518
red leaf spot, 363
smut, sori in corms, 578
tobacco ring spot virus on, 65
white break, 65
Gloeosporium sp., part of transit rot complex of Vanda orchid flowers, 373
Glomerella cingulata, hydrolysis of pectin, 474
inhibition point at various pH by helixin, 169
on peach, in Georgia, 343
tagged with C^{14}, 431
in tomato fruit, 18
Glycolysis in fungi, effect of thiram on, 475
GODFREY, G. H., 335
GOLD, A. HERBERT, 9, (12), (519)
GOLDSWORTHY, M. C., (341)
Gomphrena globosa, local lesion host for lettuce mosaic virus, 478
GOPALKRISHNAN, K. S., 338
Gossypium spp., see Cotton
GETO, S., 466
GOTTLIEB, DAVID, (4), 9, 91, (294), (465), 493
GOULD, CHARLES J., (514)
Grafting, sieve tube necrosis of lemon, 18
transmission of lilac ring spot virus, 463
GRAHAM, J. H., 466, 653
GRAHAM, K. M., 9
GRAHAM, R. W., (214)
GRAHAM, T. W., 9, (283)
Grain dust, microbiological content, 476
GRAM (see Chickpea)
GRANT, T. J., (280)
Grape (Vitis vinifera), black measles (cause unknown), reduced incidence with dormant sodium arsenite spray, 158
black rot, control with concentrated sprays, 3
downy mildew, control with concentrated sprays, 3
Pierce's disease, vectors, 533
sooty blotch, 518
storage decay, control, 514
white emperor, graft transmission of the factor, 514
Graphocephala cythura (leafhopper), vector of Pierce's disease virus, 533
Grasses, see also Cereal
Bromus inermis, 654
Grasses—*continued*
Dactylis aschersoniana, purple leaf spot, 653
glomerata, purple leaf spot, 653
Dichanthium annulatum, downy mildew, 596
dollar spot, fungicide tests, 22
Echinochloa crus-galli, Ephelis oryzae on, 634
Elymus canadensis, 654
Fescue, Rhizoctonia blight on Alta and Kentucky 31 in Louisiana, 282
Festuca arundinacea, 654
elatoir, 654
Forage grasses, purple leaf spot, 466
Harding -, host for maize leaf-fleck virus, 687
melting out, fungicide tests, 22
Phalaris arundinacea, 654
Phleum pratense, 654
Setaria italica, Ephelis oryzae on, 634
snow mold, control, 475
fungicide tests, 516
Xanthomonas streak, 387
GREEN, G. J., (403)
GREEN, JOHN M., (98)
GREEN, RALPH J., (472)
GREENLEE, R. W., (472)
GREGORY, K. F., 613
GRIMM, G. R., (465)
GROGAN, R. G., 9, 215, (518), 573
GROSSO, J. J., (5)
Growth measurements, as indications of disease resistance of tobacco to Granville wilt, 284
Growth rate of fungi in culture, measured by photometric method, 11
Growth regulators, see Plant regulators
GUBA, E. F., 112
Guignardia bidwellii, production of substance inhibitory to virus, 45
GUPTA, B. M., 45
GUTHRIE, JAMES W., 466
Guttation, correlated with fungus infections, 520
Gymnosporangium juniperi-virginianae, inheritance of resistance in apple, 19

HAFIZ, ABDUL, 422
HAGEDORN, D. J., 10, (467)
HALTIWANGER, WILLIAM L., 467
HALL, ALICE, (481)
HALL, BERNARR J., (603)
HALLER, M. H., 341
HALPIN, J. E., 10, 245, (342)
HANSEN, H. N., 479, (480)
Hansenula saturnus, inhibition point at various pH by helixin, 169
HANSON, E. W., (10), (245), 467
HANSING, E. O., 10, 10
HARDISON, JOHN R., 514
HARE, W. W., 283
HARPER, F. R., (5)
HARVEY, JOHN M., 514
HAWLEY, W. O., (131)
HAWN, E. J., 510
HEGGESTAD, H. E., 10
Helixin, see Antibiotics
Helminthosporium avenae, longevity on stored grains, 13
carbonum, infecting apparently healthy corn seed, 286
nuclear cytology and morphologic variation, 480
dictyoides, tall fescue net blotch pathogen, 22
sativum, compared with Helminthosporium victoriae, 469
effect of light on conidium production, 342
factors affecting growth and sporulation on wheat, 453
longevity on stored grains, 13
more virulent light-colored race, 472
pathogenic on cereals, 287
sp., turf melting-out pathogen, fungicide tests, 22
teres, effect of light on conidium production, 342
longevity on stored grains, 13

Helminthosporium avenae—*continued*
victoriae, breeding of oats resistant to, 482
compared with Helminthosporium sativum, 469
control on oat with helixin B, 469
on oats, wheat and sorghum, seed treatments, 10
rag-doll method for testing oat seed resistance, 12
tagged with C^{14}, 431
Hemerick, G. A., (13), (468)
Handersonula toruloidea, on walnut, 478
Henning, Robin G., 467
Hepler, Paul R., (13)
Hepting, George H., 10, 115, 438
Herbert, T. H., (284)
Herbicides, diesel oil, diseased potatoes, 511
Dow general, diseased potatoes, 511
Shell 30, diseased potatoes, 511
Hess, G. E., (343)
Heterodera rostochiensis (nematode), effect of crop rotation, 345
on Lycopersicon spp., 461
temperature in relation to viability of larvae, 113
sp., on tobacco in Connecticut, 469
Heterokaryosis, of Helminthosporium carbonum, 480
Heuberger, J. W., 11
Hevea brasiliensis, see Rubber
Hewitt, William B., 158, 514, (518)
Hibbard, A. D., (470)
Hibiscus rosa-sinensis (Chinese hibiscus), foot rot, leaf and stem blight, 144
schizopetalus, foot rot, leaf and stem blight, 144
syriacus, tbacco ringspot virus on, 478
Higgins, Daniel J., 11
Higginsia hiemalis, cherry leaf spot pathogen, 14
Hildebrand, E. M., 283
Hildebrandt, Albert C., 467
Himelick, Eugene, (472)
Hingorani, M. K., (291), 486, 526
Hirsch, Ursula, (478)
Hoadley, A. D., 113, (114)
Hochstein, P. E., 11
Hoffman, Paul, 11
Holdeman, Q. L., 283
Hollis, John P., 11, 273, 483
Holmes, Francis O., 113, 467
Holton, C. S., 635
Homalodisca liturata (leafhopper), vector of Pierce's disease virus, 533
Hooker, A. L., (465)
Hooker, W. J., 583
Hoppe, Paul E., 11
Hordeum vulgare, see Barley
Hormones, see Plant regulators
Horn, Norman L., 670
Horner, C. E., 514
Horseradish (Armoracia rusticana), white rust, resistant hybrids, 109
Horsfall, J. G., (17), (113), (457), (473), (477)
Host penetration, by Stagonospora maculata on grasses, 655
Hostic races, defined, 645
Hotson, H. H., 11
Hougas, R. W., (25, (26), 109
Hough, L. F., 11, (19)
Houston, Byron R., 12, (15), 515, (518)
Hoyman, William G., 25
Hubert, Ernest E., 515
Hughes, Morris B., (428)
Humidity, effect on longevity, of Chalara quercina, 470
of cysts and larvae of golden nematode, 469
of sporangia of Phytophthora phaseoli, 468
Humus, effect on rate of damping-off of pine seedlings, 501
reduction in damping-off of conifer seedlings, 202
Hunter, Richard, (98)
Hyacinth, black rot of bulbs, 514
Hyalospora aspidiotus, overwintering, 474
Hydrogen-ion concenrtation, adsorption of tobacco mosaic virus by carborundum, 2
Chalara quercina, effect on growth, 2, 288
control of sweet potato soil rot by adjustment, 583
effect on growth, streptomycin and vitamin B-12 production of Streptomyces griseus, 123
effect on vesicle formation by Puccinia coronata avenae, 474, 581
helixin, inhibition and residual effect, 13
inhibition point of helixin on several pathogens, 168
relation to growth of, and lycopersin production by, two Fusarium spp., 120
spore germination of Colletotrichum lagenarium, 478
sporulation range of Stemphylium solani, 7
Hydrogen sulfide, possible role in fungicidal action of sulfur, 14
Hypomyces solani, fertilization of perithecial primordia, 480
f. cucurbitae, inheritance of sex, 480
Hypoxylon sp., on aspen, factors affecting, 463
Hyre, R. A., 468, 481

Indole acetic acid, see also Plant regulators
metabolic product of Ustilago zeae, 24
Inga edulis, spot anthracnose, 12
Inheritance of resistance, apple to cedar-apple rust, 19
barley to loose smut, 367
Brassica to black rot, 497
horseradish hybrids, white rust, 109
lima bean to downy mildew, 43
oat, to black stem, 16
to crown rust, 17
onion to downy mildew, 22
potato, multiple, 483
Sea Island cotton to Fusarium wilt, 287
soybean to frog-eye leaf spot, 660
spinach to cucumber virus 1, 305, 16
sugarcane to red rot, 282
tobacco, multiple disease resistance breeding program, 482
to black shank, 288
tomato, to anthracnose, 113
to late blight, 197
to tobacco mosaic virus infection, 467
Inhibition, in vitro antibiosis compared with soil test of actinomycete control of Pythium root rot, 284
of cucumber mosaic virus by plant extracts, 349
of virus infection, by fungal growth products, 240
Inhibition of seed germination, with extract of wood of Prunus spp., 285
Injuriogenic disease, defined, 283
Inoculation techniques, brown spot of corn, evaluation, 284
by tooth pick tip, for weak pathogens, 5
comparison of two methods on sporulation in culture, 7
methods used for evaluating disease resistance, 628
of cotton seedlings with Verticillium wilt, 288
uredospores on cereal leaves, 340
Inoculum potential of soil, tobacco black shank, 286
Insecticides, benzene hexachloride, amorphous compared with crystalline form, 200
Chlordane, onion maggot control, 15
DDT, amorphous compared with crystalline form, 200
onion maggot control trial, 15
Dieldrin, onion maggot control, 15
Heptachlor, onion maggot control, 15
lindane, onion maggot control, 15
octa-methylpyrophosphoramide, for control of sweet potato internal cork vector, 287
organo-phosphorous, as nematocides in vapor phase, 466
sodium arsenite, black measles of grape reduced by, 158
Systox, onion maggot control trial, 15
trial for control of root knot nematodes, 343
toxaphene, onion maggot control trial, 15
Insects, corn borer wounds as infection court for corn stalk rot, 20
feeding periods of aphids in relation to transmission of beet mosaic virus, 252

Insects—*continued*
multiplication in leafhopper vector of aster yellows virus, 14
multiplication of wound tumor virus in its vector, 269
peach silver mite, responsible for yellow spot, 443
Insects as vectors, aphids, alfalfa mosaic virus, 261
barley, yellow dwarf virus, 15
beet mosaic virus, comparison of four species, 252
maize leaf-fleck virus, 683
oat blue dwarf, 471
oat red leaf, 471
potato leaf roll, 540
temperature effect on strawberry yellows virus complex in the vector, 517
grasshopper, transmission of tobacco viruses, 355
leafhoppers, alfalfa witches' broom, density of planting affecting spread of disease, 649
Dalbulus maidis, inability of aster yellows virus to multiply in, 113
Macrosteles divisus, inability of corn stunt virus to multiply in, 113
multiplication of aster yellows virus in the vector, 14, 59
new curly top virus strain in Brazil, 396
papaya bunchy top virus, 3
Pierce's disease of grape and alfalfa, 533
recovery of virus from non-vector insects, 470
wound tumor virus, multiplication of the virus in its vector, 269
Ipomea batatas, see Sweet potato
Iris, black rot of bulbs, 514
Irrigation, effect on disease development of avocado root rot, 35
Ishii, Mamoru, (690)
Isolation technique, for soil-borne phycomycete species, 341
Itersonilia sp., parsnip canker pathogen, 23
Ivanoff, S. S., 12

Jackson, Elsa L., 480
Jackson, Herbert Spencer, a biographical sketch, 406
Jackson, L. W. R., 47
Jacobson, Louis, (478)
James, M. O., 144
Janson, B. F., 152
Jeffers, W. F., (342), 468, (473)
Jehle, R. A., 342
Jenkins, Anna E., 12, (342)
Jenkins, Wilbert A., 284
Jensen, D. D., (9), 12
John, B. G., Jr., 343, (470)
Johnson, Folke, (513)
Johnson, H. G., (18)
Johnson, J. Ralph, 284
Johnson, James, (8), 12
Johnson, Leander F., 12, 284, 468
Johnson, T., 403
Johnson, T. W., Jr., 342
Jones, Leo E., 515
Jones, Walter, 515
Jorgensen, Hans, (43)
Juglans, spp., see Walnut
Jump, J. A., (338)

Kahn, Robert P., 13
Kalanchoë daigremontiana, gall formation on, by morphological varients of Agrobacterium tumefaciens, 8
Kale, Fusarium wilt, 256
Kaufman, J., (112)
Kazmaier, Harold E., 13
Keil, Harry L., 113
Keitt, G. W., (13), (20), (168), (447), (479), 480, (506)
Kelman, Arthur, 284, (628)
Kendrick, James B., Jr., 515, (603)
Kendrick, James B., Sr., (9), 25
Kenknight, Glenn, 285, 468
Kernkamp, M. F., 13, 468
Keyworth, W. G., 113, 311
Kilpatrick, R. A., 285
King, T. H., (7), 468
Kingsolver, C. H., (340)
Kirkpatrick, Hugh C., 540
Klomparens, William, (22)
Klotz, L. J., (512)
Knowles, P. F., (515)
Kobel, F., 515
Kohlrabi, Fusarium wilt, 256
Kommedahl, Thor, 468
Kozlowski, Theodore T., 405
Kreitlow, K. W., (342), 469, (568)
Krog, Norman E., (468)
Kunkel, L. O., 27
Kuntz, J. E., (2), 13, (463)

Labiatae, genera infected by races of Puccinia menthae, 2
Legenaria leucantha (bottlegourd), mosaic disease on, 149
Lambertella pruni, production of substance inhibitory to virus, 45
Lane, George H., 25
Larson, R. H., 25, (26), (162), (183), (316), 469
Leach, J. G., (476), 537
Leaf and stem blight, of ornamental hibiscus, 144
Leaf clearing, histological, for examination of spore germination, 352
Lear, Bert, 193, (481), 489
Leben, Curt, 13, (20), 168, 331, 352, (447), 469, (506)
Legumes, seed treatments, 467
Lehman, S. G., 285
Lemon, brown rot, fungicide tests, 512
shell bark, control by pruning, 512
sieve tube necrosis, related to grafting, 18
Leone, Ida, (112)
Leptographium sp., effect on translocation in pine, 515
Leptosphaeria avenaria, incitant of black stem of oats, 16
Lethum australiense see Virus(es), tomato spotted wilt
Lettuce, bacterial soft rot, 112
downy mildew, mode of infection, 513
drop, role of organic matter in soil, 518
mosaic, control, 573
Lewis, C. E., 342
Lewis, Ralph W., 657
Lewis, W. D., (1)
Light, effect on concentration of cucumber virus 1 in spinach, 308, 4
effect on condidium production in some species of Dematiaceae, 342
effect on flat rust development, 208
effect on rate of damping-off of pine seedlings, 501
effect on uredial development of Puccinia graminis avenae, 527
high intensity, increases chrysanthemum stunt symptoms, 341
required for wilt toxin production in culture, 8
Lilac, powdery mildew, absorption of sulfur by mycelium, 15
Lilly, V. G., (2)
Limber, Donald P., 578
Linn, M. B., (133)
Liquidambar styraciflua (sweet gum), bark canker, 16
Lithocarpus densiflorus (tanoak) susceptible to oak wilt fungus, 3
Livingston, J. E., 221
Locke, Seth B., (514), 516
Lockwood, J. L., 447
Logsdon, Charles E., 25
Longevity, in soil of Xanthomonas translucens, 387
in storage of several cereal seed fungi, 13
of Ditylenchus nematode, 464
Lownsbery, B. F., (345), 469, 651
Lownsbery, B. F., Jr., 13, (131)
Lownsbery, J. W., (13), (131)
Lownsbery, J. W., (13), (651)
Lu, Shi I., 480

Lucas, G. B., 285, (286)
Luke, Herbert H., 286, 469
Lupine, cover crop, breeding program, 283
Lupinus angustifolius, cover crop in Florida, 283
luteus, cover crop in Florida, 283
Luttrell, E. S., 469, 607
Lycomarasmin, possible role in chemotherapeutic treatment of Fusarium wilt, 465
role in tomato wilt, 18
Lycopersicon esculentum, see Tomato
Lycopersicon spp., early blight of, 467
susceptibility to golden nematode, 461
used to determine physiologic races of tomato anthracnose pathogen, 18
Lycopersin, factors affecting production of, by Fusarium lycopersici and F. vasinfectum, 119
Lyophilization of Puccinia uredospores, 263, 480

Machacek, J. E., 13
Macrophomina phaseoli, on bean, 607
on soybean, inoculation method, 5
Macrosiphum dirhodum (aphid), barley yellow dwarf virus vector, 15
granarium, barley yellow dwarf virus vector, 15
pisi, vector for alfalfa mosaic virus, 261
solanifolii, vector for alfalfa mosaic virus, 261
Macrosteles divisus (leafhopper), multiplication of aster yellows virus in, 59
multiplication of aster yellows virus in the vector, 14
not a vector for alfalfa witches' broom virus, 28
study on specific transmission of viruses, 663
Mai, W. F., 113, (193), 345, 461, 469, 481, (489)
Makila, Armas, (465)
Maleic hydrazide, see also Plant regulators
effect on phosphorus distribution in tomato, 22
Malic acid, basis of resistance in chickpea to Mycosphaerella blight, 422
Maramorosch, Karl, 14, 59, 113, 470, 663
Marcus, Carlton P., Jr., 342
Marmor lactucae, local lesion hosts for, 478
tabaci, see also Virus, tobacco mosaic
related to internal browning of tomato, 591
Marsden, David H., 113, 300
Marshall, B. H., Jr., 342
Marshall, N. L., 470
Martin, J. P., Jr., 342
Martin, Mary M., (493)
Martin, Norma, 294
Martin, W. J., (7)
Mason, Curtis L., 14
McBeth, C. W., 484
McCallan, S. E. A., 14, (15), (470), (477)
McClellan, W. D., 407
McClure, Thomas T., 14
McColloch, L. P., 425
McGrew, John R., 343
McKeen, C. D., 14, 14
McLaughlin, W. D., 470
McLean, D. M., (514), 516
McLean, John G., 26
McWhorter, F. P., (518)
von Mechow, Joyce, (469)
Medicago falcata, Volutella sp. parasitic on, 5
sativa, see Alfalfa
Meiners, J. P., 516
Melampsora epitea, overwintering, 474
lini, effect of temperature on viability and germination of spores, 204
lysis of uredospore germ tubes by lime-sulfur, 70
Melanogenesis, in Streptomyces scabies, related to toxin formation, 483
in Streptomyces scabies, substrate for, 273
Melanoplus differentialis (grasshopper), transmission of tobacco viruses by, 355
Mellor, Frances C., 516
Meloidogyne incognita v. acrita (nematode), on asparagus, 6
spp., identification by host reaction, 17
on snapdragon, 637, 641
Mentha spp., mint rust on, 2
Menzies, J. D., 516, 649
Merwarth, F. L., (114)
Meso-inositol, possible role in production of lycopersin by Fusarium vasinfectum, 121
Methyl-bis (β-chloroethyl) amine, used to induce virus mutation, 25
Micronutrients, see also Nutrition of microorganisms:
specific elements:
boron, in apple leaves and fruits, 464
role in celery adaxial crack, 603
cobalt, effect on production of streptomycin by Streptomyces griseus, 123
copper, effect on vitamin requirement of Coniothyrium fuckelii, 468
pigment production in Fusarium lycopersici and F. vasinfectum, 122
zinc, effect on growth of Fusarium lycopersici and F. vasinfectum, 121
effect on vesicle formation by Puccinia coronata avenae, 474, 581
growth and zinc content of tomato plants sprayed with zineb, 133
vitamins:
biotin, effect of copper on requirement of, by Coniothyrium fuckelii, 468
isoinositol, effect of copper on requirement of, by Coniothyrium fuckelii, 468
thiamin, effect of copper on requirement of, by Coniothyrium fuckelii, 468
vitamin nutrition of Alternaria solani, 657
vitamin nutrition of Chalara quercina in culture, 463
Microsphaera alni, absorption of sulfur by mycelium, 15
Middleton, John T., (515), 516, 603
Mikola, Peitsa, 202
Milbrath, J. A., (26), 347, (515), 516, (693)
Miller, Harold J., 114, 470
Miller, Julian H., 286
Miller, P. W., 517
Miller, Lawrence P., (14), 15, 470, (477)
Miller, W. E., (340)
Millikan, D. F., 470
Mills, W. R., 26
Mineral element deficiency, see also Nutrition, and Micronutrients:
boron, celery adaxial crack, 603
content of apple leaves and fruit, 464
zinc, in tomatoes, provided for by zineb spray, 133
Misra, A. P., 204
Mohajir, Abdul-Rasheed, 367
Moisture, in cured tobacco, related to chlorine content and development of stem rot, 10
soil, effect on development of safflower root rot, 33
Mold counts, in processed black rasperries, controlled by various fungicidal sprays, 2
Monarda spp., mint rust on, 2
Monardella spp., mint rust on, 2
Monilinia fructicola, control of fruit loss with volatile chemicals, 19
control of peach brown rot with DHA-S, 19
effect of actidione on conidia germination, 21
fungicide tests on peach fruit, 7
post-harvest treatment for peach, 341
Monilochaetes infuscans, sulfur soil treatment, 590
Mooar, Marie, (363)
Moon, H. H., (341)
Moore, E. L., (285)
Moore, J. Duain, (20), (22), 470, (477)
Moore, M. B., 471
Moorhead, Ellen L., 471
Moreira, Silvio, (280)

MORGAN, O. D., JR., 343, 471
Morphological variation of microorganisms, induced mutants of Pyrenochaeta terrestris, 188
MORRIS, C. L., 681
MORRIS, H. E., (101)
Mucor sp., associated with corn stalk rot, 20
MULLIN, R. S., 15
MUNCIE, J. H., (512)
MURAKISHI, HARRY H., 178, 339, 517
MURNEEK, A. E., 57
MURPHY, H. C., (16), (474), 482
Mushroom crops, control of nematode diseases of, 4
Muskmelon, Fusarium wilt, virulent strain, 465
  viruses on, 8
Mutations induced in fungi by incorporating fungicides in the medium, 471
Mycorrhiza, associated with potato phloem parenchyma, 25
Mycosphaerella melonis, on cucumber, 14
  rabiei, basis of resistance in chickpea to, 422
  sp., sooty blotch of Vitis californica, 518
Myrica carolinensis, yellows virus disease, 17
Myzus circumflexus (aphid), vector for beet mosaic virus, 252
  persicae, vector for alfalfa mosaic virus, 261
    vector for beet mosaic virus, 252
    vector for maize leaf-fleck virus, 683
  solani, vector for beet mosaic virus, 252

NARASIMHAN, M. J., 596
Narcissus, Fusarium basal rot, effect of temperature, 407
NARIANI, T. K., (149)
NATTI, JOHN J., 481
Nectria canker, eradication experiment, 287
NELSON, MARJORIE, (481)
NELSON, PAUL E., 517
NELSON, RAY, 363
Nematocides, assay methods, 484
Nematocides, specific compounds, see also Soil fumigants
  methyl bromide, for disinfestation of potato handling equipment, 489
  organo-phosphorous insecticides on foliar nematode, 466
Nematodes, anabiotic survival of Ditylenchus, 464
  awl — (Dolichodorus heterocephalus), 483
    on celery, 175
    on Chinese water chestnut, 114
  control progress report, 484
  dagger —, 483
  detection methods, 484
  earcockle —, role in tundu bacterial disease of wheat, 291
  ectoparasites on various field crops, 9
  factor in cracking of sweet potatoes, 15
  factor in selection of Fusarium wilt resistant cotton, 287
  foliar —, nematocidal action of various organo-phosphorous insecticides, 466
  golden —, continuous potato cropping with yearly soil fumigation, 481
    crop rotation, 345
    effect of humidity on longevity of cysts and larvae, 469
    hatching stimulants from potato roots, 466
    methyl bromide disinfestation of potato handling equipment, 489
    root galls on tomato, 466
    soil fumigation experiments, 193
    susceptibility of Lycopersicon spp. to, 461
    temperature in relation to viability, 113
  internal parasitism of plants, 484
  on celery, 131
  on citrus roots, 1
  on mushroom crops, control, 4
  on rice, control of white tip, 6
    laboratory culture, 21
    nematocide screening, 463
  on rye cover crop, comparison of phytotoxicity of two nematocides, 6
  Paratylenchus hamatus, on celery, 651, 13
Nematodes—*continued*
  root-knot, control trials with Systox, 343
    effect of potassium nutrition, 15, 343
    entry of larvae into roots, 474
    identification of species by host reaction tests, 17
    life history of five spp., 20
    on asparagus, 6
    on peanut, 282
    on snapdragon, 637, 641
  sting — (Belonolaimus gracilis), 483
    associated with cotton wilt, 283
    on peanuts, 470
    on strawberry, celery, and sweet corn, 173
  stubby root —, 483
  tobacco black shank, contributing factor, 15
  tobacco cyst, in Connecticut, 469
  Tylenchulus semipenetrans, on olive, 77
Nephelometer, construction of a simple —, 171
Neurospora sitophila, inhibitory action on virus infection, 240
NEWHALL, A. G., 15, 212
NEWTON, NELSON, 79
NICHOLS, CARL W., 517, 579
Nicotiana debneyi, source of blue mold and black root rot resistance in tobacco, 482
  glutinosa, concentration of turnip virus 1 related to host nutrition, 477
    root necrosis virus, 464
  longiflora, source of resistance to tobacco black shank, 288
    source of wildfire resistance in tobacco, 482
    source of wildfire resistance in Wisconsin tobacco, 12
  multivalivis, concentration of turnip virus 1 related to host nutrition, 477
  spp., source of resistance to tobacco anthracnose, 343
  tabacum, see Tobacco
NIELSEN, L. W., 625
Nigrospora oryzae, associated with corn stalk rot, 20
Nitrogen mustard, induced biochemical mutants in Venturia inaequalis, 479
  induced mutants of onion pink root fungus, 9, 183
  used to induce virus mutation, 25
Nocardia **vaccinii** n. sp., gall incitant on blueberry, 249
Nodule bacteria, in soybean, effect of fungicide treatment, 19
Non-parasitic diseases:
  fluorine toxicity, root and leaf content, 112
  lemon sieve tube necrosis related to grafting, 18
  poplar, yellow, blister shake, 21
  potato, mahogany browning, effect of railroad transit, 112
    stem-end browning, 25
    tuber discoloration, 25
    tuber heat injury, effect of storage temperatures, 344
  spray injury, storage shrinkage of apple correlated with russeting, 344
Nursery stock, role in dissemination of soil pathogens, 478
NUSBAUM, C. J., 15, 286
Nutrition of hosts and suscepts, see also Mineral element deficiency
  foliar sprays:
    boron, control of snow mold, 5
    effect on celery adaxial crack, 603
    tomato Fusarium wilt index increased, 3
    zinc from zineb spray on tomato, 133
  specific elements:
    chlorine, in cured tobacco, development of stem rot, 10
    nitrogen, effect on concentration of cucumber virus 1 in spinach, 377
    phosphorus, effect of stunting agents in tomato, 22
      effect on concentration of cucumber virus 1 in spinach, 377
      effect on concentration of turnip virus 1 in Nicotiana spp., 477
    potassium, effect on concentration of cucumber virus 1 in spinach, 377

Nutrition—*continued*
effect on root-knot nematodes, 15, 343
specific plants:
celery, boron deficiency, 603
Nicotiana spp., concentration of turnip virus related to host nutrition, 477
spinach, effect of nutrition on resistance to cucumber virus 1, 303
effect on concentration of cucumber virus 1 in, 377, 4
tomato, zinc provided in zineb, 133
Nutrition of microorganisms, see also Hydrogen-ion concentration, Micro-nutrients and Plant regulators
specific elements:
carbon, relationship between substrate sugars and sporulation, 7
requirements of Chalara quercina, 288
sources for growth of Chalara quercina, 2
sources for growth of Chalara quercina in culture, 463
sources, relation to growth and pigment in Fusarium spp., 120
nitrogen, requirements of Chalara quercina, 288
amino acid metabolism in melanogenesis of Streptomyces scabies, 483
inorganic and amino acid sources for growth of Chalara quercina, 2
sources for growth of Chalara quercina in culture, 463
zinc, vesicle formation of Puccinia coronata avenae, 474
specific organisms:
Alternaria solani, vitamin nutrition, 657
Chalara quercina, 2, 463, 288
Coniothyrium fuckelii, effect of copper on vitamin requirements, 468
Fusarium spp., relation of carbon source to growth and pigment production, 120
Hendersonula toruloidea, 478
Puccinia coronata avenae, effect on vesicle formation, 474, 581
Nutritive spray, see Nutrition, hosts and suscepts, foliar sprays
NYLAND, GEORGE, 517, (517)

Oak (Quercus spp.),
canker, eradication experiment, 287
wilt, chemotherapy, test of 37 organic compounds, 11
diploidization of pathogen, 537
factors influencing symptom development, 13
host response, plugging of xylem, 2
liberation of spores, 537
mycelial mat production by pathogen in Pennsylvania, 681
macroscopic sign of pathogen in natural infection 6
natural reservoir and spore liberation of pathogen, 476
potential source of inoculum, 531
perithecial stage in dissemination, 691
quick test for pathogen, 1
rapid determination by liquid culture, 57
woody hosts, 3
Oat (Avena sativa),
bioassay of Ceresan M on treated kernels, 222
black pstem, varietal resistance, 16
blue dwarf, in Minnesota, 471
crown rust, varietal response to physiologic races of the pathogen, 474
varietal resistance to Race 45, 17
disease resistance breeding, 482
leaf anatomy affected by smog, 558
longevity in storage of several cereal seed fungi, 13
mosaic virus, new, in Calif., 12
red leaf, in Minnesota, 471
root rot, in Tennessee, 287
Septoria black stem, in Minnesota, 466
smut, seed treatment, 10

Oat—*continued*
stem rust, morphological and pathological studies of 3 races of incitant, 486
races of incitant, 526
Victoria blight, comparison of seed treatments, 10
control with helixin B, 469
mass testing for resistance, 12
resistant varieties, 482
yellow dwarf virus of barley on, 15
OLIEN, CHARLES R., (471)
Olive, citrus-root nematode on, 77
OLMSTED, DONALD S., 26
Onion, blast, control, 15
blast and mildew, control with carbamates, 212
downy mildew, inheritance of resistance, 22
maggot, insect control, 15
mildew, 15
pink root fungus, pathogenicity of induced mutants, 9, 183
purple and brown blotch, 20
smut, control, 469
smut and maggot, combination control, 15
Orange, citrus-root nematode, leaf mottle, 1
Orchard grass, purple leaf spot, 466, 653
Orchid, Fusarium wilt and root rot, 517
leaf and petiole mottle virus complex, electron microscope studies, 79
virus diseases, 12
virus particles from several genera, 9
Cattleya, new virus disease in Hawaii, 517
viruses, serological detection, 478
Dendrobium, leaf mosaic virus, 339
Vanda, mosaic virus on, 178
transit rot of flowers, 373
Organic matter, role in lettuce drop, 518
Ornamentals, silky thread blight, seasonal relations, 287
ORSENIGO, M., (38)
Oryza sativa, see Rice
OSWALD, JOHN W., (11), 15, 518
OTEIFA, B. A., 15, 343
OWEN, JOHN H., 286
OWENS, ROBERT G., 471

PALM, ELMER T., 518
PALMER, H. C., 472
Pantothenic acid, content of rust infected bean leaves, 481
Papaya (Carica papaya), bunchy top virus, 3
Parasitism, related to physiologic specialization in Colletotrichum lini, 18
role of toxins, 483
Paratylenchus hamatus (nematode), on celery, 13, 651
PARKER, M. W., (341)
Parsnip, canker, 23
Pathic races, defined, 645
PATTON, R. F., 16
Peach, anthracnose, in Georgia, 343
bacterial spot, dormant spray for control, 14
brown rot, control of fruit rot, 19
organic vs. inorganic fungicides for control of, 7
storage and transit losses, 19
fruit rots, post-harvest treatment, 341
phony disease, acid test studies, 468
review of control program, 286
wild plum reservoir, 287
ringspot, resistance conferred by mild strain, 512
viroses, hot water treatment, 517
X disease, dodder transmission of the virus, 475
yellow spot, mite injury, 443
Pea (Pisum sativum),
damping-off, seed treatment, 470
Pythium seed decay and seedling blight, 516
seed treatment, 10
varietal response to various dry and slurry applications, 55
viroses, cross-protection tests, 10

Peanut (Arachis hypogaea),
root knot nematode, soil fumigation, 282
southern blight, factors in control, 282
sting nematode, 470
Pear, fire blight, rapid inoculation of seedlings, 341
Peck, Harry D., Jr., (5)
Pectinase activity, of fruit rot fungi, 474
Penetration and infection of tobacco by black shank pathogen, 286
Penetration of leaf by Phytophthora infestans, 16
Pepper (Capsicum frutescens),
damping-off, caused by Aphanomyces cladogamus, 14
fruit morphology related to internal rots, 7
Verticillium wilt, factors affecting pathogenicity of incitant, 515
Peppermint (Mentha piperita),
root and rhizome rot, 514
Verticillium wilt, control in planting stock by heat treatment, 472
Peridermium **appalachianum** n. sp., a new rust on Virginia pine, 10, 115
Peronospora destructor, on onion, control, 212
resistance to, 22
Perry, V. G., (173)
Persons, T. D., 286
Perersen, D. H., 343
Peterson, L. C., (26)
Peterson, Lewis E., (583)
Peterson, W. H., (613)
Petunia, phytotoxic response of seedlings to formaldehyde, 171
pH, see Hydrogen-ion concentration
Phaseolus spp., see Bean
Phloem, bidirectional movement in, 385
Phloroglucinol test, evaluation for potato virus leafroll diagnosis, 481
for phony disease, 285
Phoma sp., inciting rootlet rot of alsike clover, 514
Phomopsis cinerescens, on fig, 513
Phosphate effect in virus inoculations, 137
Photoperiod, effect on concentration of cucumber virus 1 in spinach, 308
Phragmidium rubi-idaei, on raspberry, 477
Phyllosticta sojaecola, on soybean, 342
Physalis floridana, immunological relationship of potato leaf roll virus strains, 26
Physoderma maydis, inoculation into corn, technique evaluation, 284
Physalospora ilicis, 479
obtusa, on apple, 288
tucumanensis, on sugar cane, 282
Physiogenic disease, defined, 283
Physiologic diseases, see Non-parasitic diseas s
Physiologic specialization,
developmental races, defined, 645
environmental races, defined, 645
hostic races, defined, 645
pathic races, defined, 645
cereal rusts, biochemical differences between uredospores, 3
oat crown rust, 474
onion purple and brown blotch pathogen, 20
root-knot nematodes, host reaction, 17
wheat powdery mildew, 8
wheat stem rust, survival of races of the pathogen, 479
Collectotrichum phomoides, 18
lini, 18
Fusarium bulbigenum var. niveum on muskmelon, 465
conglutinans, races inciting Crucifer wilts, 1, 255
oxysporum f. perniciosum on mimosa, 694
Phytophthora fragariae, races of, 468
infestans, appearance and survival of new races, 481
on tomato and potato, 645
races developed on potato hybrids, 26
races on tomato, 461
Physiologic specialization—*continued*
Pseudomonas tabaci, pathogenicity compared on tobacco and soybean, 4
Puccinia graminis avenae, 526
menthae, races, 2
Streptomyces scabies, races on potato, 26
Physiologic specificity of pathogenesis, 483
Phytolacca decandra (Poke), cucumber mosaic transmission studies, 6
Phytomonas tabaci, resistance, 12
Phytophthora cactorum var. applanata, hibiscus foot rot, 144
cinnamomi, on avocado, 35
soil fungicide tests, 24
citrophthora, on lemon, control, 512
drechsleri, on safflower, 21, 32
susceptibility tests, 219
fragariae, physiologic races, 468
infestans, appearance and survival of new races, 481
breeding potatoes for immunity to late blight, 277
effect of temperature on viability of sporangia in the field, 482
leaf penetration, 16
pathogenesis of late blight correlated with meteorological data, 481
physiologic races, 645
powdery scab as an infection court for, 343
on potato, 26
on tomato, 461
resistance to, in tomato, 197
spore dispersal hypothesis, 323
palmivora, hibiscus leaf and stem blight, 144
on rubber, 547
parasitica var. nicotianae, effect of soil fumigation, 285
estimating inoculum potential of soil, 286
host-parasite relations in resistant and susceptible tobacco varieties, 286
nematodes as a factor in tobacco black shank severity, 15
wilt mechanism in tobacco, 472
phaseoli, on lima bean, 43
longevity and zoospore germination study, 468
sp., inciting turnip storage rot, 515
spp., substances stimulatory to sexual stage, 24
Phytotoxicity, antibiotics, on agar plate test for virus inhibition, 331
comparison of two nematocidal soil fumigants on rye cover crop, 6
copper sulfate dormant spray on peach, 14
formaldehyde residue in flats, 171
helixin, 168
related to lipid-solubility, 17, 457
trichloroethane and tetrachloroethane, to peach fruit, 342
Pigment production, by Fusarium lycopersici and f. vasinfectum, 119
stimulation of melanogenesis in Streptomyces scabies, 273
Pimpernel, water (Samolus parviflorus), curly top virus on, 2
Pine, jack (Pinus banksiana), damping-off, effect of humus, 202
loblolly (P. taeda), needle browning, 282
red (P. resinosa), needle droop, 16
Scots (P. sylvestris), damping-off, affected by soil fertility and illumination, 501
shortleaf, (P. echinata), effect of little leaf on seed quality, 57
Virginia (P. virginiana), a new rust on, 10, 115
a new rust, 10, 115
western white, (P. monticola), pole blight, 515
white (P. strobus), blister rust, local control, 475
Piricularia oryzae, effect of light on conidium production, 342
Pirone, P. R., 16
Plakidas, A. G., 16, (144)

Plant disease forecasting, potato late blight, 482
correlated with meterological data, 481
Plant regulators,
actidione, fruit development arrested in cherry, 14
indoleacetic acid, produced by Exobasidium camelliae var. gracilis in culture, 147
produced by Ustilago zeae, 24
indolebutyric acid, effect on tobacco mosaic virus, 517, 579
effect on virus concentration in cultured tissue, 515
maleic hydrazide, used in fungicide screening technique for snap bean powdery mildew, 114
naphthaleneacetic acid, effect on tobacco mosaic virus, 517, 579
effect on growth of tobacco mosaic virus in tissue culture, 467
pentachlorobenzoic acid, used in fungicide screening technique for snap bean powdery mildew, 114
various, effect on disease resistance of tomato to Fusarium wilt, 465
Platanus acerifolia (London plane), bark canker, 16
canker stain, 236
occidentalis, canker stain, 236
Plectodiscella veneta, fungicide tests, 23
Pleospora sp., on gladiolus causing red leaf spot, 363
Plum, myrobalan (Prunus cerasitera),
indexing for viruses, 512
wild, phony disease, 282, 287
POLLARD, E. C., 472
PON, D. S., 472
POOLE, D. D., 16
Poplar, yellow, blister shake, 21
POPP, W., 472
Populus spp., see Aspen
PORTER, C. A., 518
PORTER, C. L., 472
Potato (Solanum tuberosum),
alfalfa witches' broom virus in, 27
bacterial ring rot, 25
effect of railroad transit, 112
bacterial soft rot, effect of railroad transit, 112
role of suberization and periderm formation, 481
brown rot, inoculation methods, 629
calico virus, strains, 516
disease resistance, breeding, 483
Fusarium rot, effect of railroad transit, 112
golden nematode, continuous cropping, 481
crop rotation, 345
soil fumigation study, 193
green dwarf induced by beet curly top virus, 516
heat injury of stored tubers, 344
internal browning, 25
late blight, appearance and survival of new races of the incitant, 481
breeding for immunity, 277
disease forecasting, 482
genetic factors for resistance to the races of the pathogen, 26
meterological correlation, 481
powdery scab as an infection court for, 343
races of pathogen, 645
temperature effect on viability of incitant sporangia, 482
late blight rot, effect of railroad transit, 112
leaf roll, aphids as vectors, 540
evaluation of phloroglucinol test, 481
influence on ascorbic content of tubers, 516
leaf roll virus, strains, 26
leaf roll net necrosis, effect of railroad transit, 112
mahogany browning effect of railroad transit, 112
mycorrhiza-like mycelium associated with tubers, 25
powdery scab, as infection court for Phytophthora infestans, 343
scab, disease development related to tuber size, 297
resistance to, 26
Potato—*continued*
scurf, control with chlorinated phenols, 512
seed piece decay, control, 26
dry fungicides, 25
fungicide tests, 26
stem-end browning (non-parasitic disease), 25
stem end browning (virus), effect of railroad transit, 112
tuber discoloration, factors, 25
tuber diseases, effect of railroad transit, 112
Verticillium wilt, varietal resistance, 25, 26
viroses, control by chemical roguing, 511
"virus-free" plants yielding rod-like particles, 466
X virus, transmitted by grasshopper in tobacco, 357
POUND, GLENN S., (4), 16, 83, 301, (306), (377), (448), (473), (477)
Powdery mildew, control with Iscothan on cantaloupe, 335
snap bean, technique for fungicide screening tests, 114
wheat, reaction of susceptible and resistant varieties, 8
POWERS, HARRY R., JR., 472
PRICE, W. C., (8), 16, (45), (240), (471)
PRINCIPE, P. A., 123
PRISTOU, R., 16
PROBST, A. H., (660)
Prunus americana, reservoir for peach phony disease virus, 287
avium, tobacco ringspot virus on, 478
spp., phony disease on wild plum, 282, 287
Pruning, for control of Dutch elm disease, 113
lemon trees for control of shell bark, 512
white pine blister rust, local control, 475
Pseudomonas caryophylli, inoculation studies on carnation, 342
glycina, halo strain on soybean, 299
lachrymans, on cucumber, 105
marginalis, on lettuce and escarole, 112
phaseolicola, compared with Pseudomonas glycina (halo strain) on soybean, 299
toxin production, 475
solanacearum, artificial inoculation of tomato, 23
evaluation of tobacco resistance to, 284
inoculation methods used for evaluating disease resistance of tomato, 628
tabaci, comparison of six isolates, 4
Puccinia asparagi, in Illinois, 13
coronata, lyophilization of uredospores, 263
physiologic specialization in oat, 474
sugar and amino acid composition of uredospores, 3
avenae, vesicle formation, influence of pH and zinc, 474, 581
carthami, on safflower, 5, 211
control by seed treatment, 108
graminis, lyophilization of uredospores, 263
avenae, difference found in sugar and amino acid composition of uredospores among two races of, 3
morphological and pathological studies of three races, 486
physiologic races, 526
uredospore inoculation technique, 340
secalis, owerwintering of uredospores, 403
tritici, differences found in sugar and amino acid composition of uredospores among four races of, 3
fungicide test, 465
inhibition and counter-inhibition, 11
sorus production on albino barley seedlings, 177
survival ability of races, 479
uredospore inoculation technique, 340
glumarum, lysis of uredospore germ tubes by lime-sulfur, 70
spp., lyophilization of uredospores, 480
triticum, mutation, 479
Pullularia sp., role in needle droop of red pine, 16
PURDY, LAURENCE H., JR., 518
Pycnathemum spp., mint rust on, 2
Pyrenochaeta terrestris, pathogenicity of induced mutants, 9, 183

Pyridine, technique for clearing leaves, 352
Pyrophyllite, used in inoculation technique for pear seedlings, 341
Pythium acanthicum, on sterilized straw in soil, 20
arrhenomanes, antagonism toward, 468
in soil, 12
inhibition by actinomycetes, 284
by bacteria, 464
by fungi, 286,469
observations on, 4
pathogenic on cereals, 287
irregulare, jack pine seedlings damping-off, 202
on sterilized straw in soil, 20
paroecandrum, on sterilized straw in soil, 20
spp., inciting damping-off and root rot of alfalfa, 613
pathogenicity on red clover seedlings, 10, 245
on corn, 467
on pea, 516
sp., on peppermint, 514
ultimum, jack pine seedlings, damping-off, 203

Quarantine, effect in control of peach phony disease, 286
Quercus spp., see also Oak
acutissima (Asiatic oak), susceptible to oak wilt fungus, 3
dentata (Asiatic oak), susceptible to oak wilt fungus, 3
falcata, spot anthracnose on, 12
laurifolia, dagger nematode on, 484

Raabe, R. D., 17, 448, 473
Radiation, see also Light
gamma, possible use in plant disease therapy, 599
ultra-violet, induced biochemical mutants of Venturia inaequalis, 479
induced sporulation of Stemphylium solani in culture, 7
X-ray, possible use in plant disease therapy, 599
used to induce mutations in lupine cover crop breeding program, 283
Radioactive elements, as tracers in study of microbial toxins, 483
C^{14}, labeled fungus spores and mycelium, 23, 431
respiratory metabolism of Streptomyces scabies, 5
study of fungicidal action, toxicity and absorption, 478
Cs^{137}, study of fungicidal action, toxicity and absorption, 478
Co^{60}, possible use in plant disease therapy, 599
P^{32}, effect of stunting agents on phosphorus distribution in tomato, 22
effect on tobacco mosaic virus content of tobacco plants, 519
possible use in plant disease therapy, 600
study of fungicidal action, toxicity and absorption, 478
to measure translocation in pole blighted pine, 515
Rb^{86}, translocation in oak wilt, 2
study of factors influencing oak wilt development, 13
S^{35}, studies on lilac powdery mildew, 15
breakdown products of dithiocarbamates, 477
labeled dithiocarbamates, fungicidal action, 472
study of fungicidal action, toxicity and absorption, 478
Radish (Raphanus sativa),
Fusarium wilt, 1
physiologic races, 255
mosaic, study of virus particle, 623
Rankin, Harvey W., 287
Raski, D. J., 484
Raspberry (Rubus idaeus, R. occidentalis),
anthracnose, comparison of fungicides, 8, 23
bacterial fire blight, 114
mold count in processed fruit, effect of various fungicidal sprays, 2
spur blight, comparison of fungicides, 8
storage rots, controls, 24
Verticillium wilt, 8
yellow rust, 477
Rawlins, W. A., (15), (212)
Raychaudhuri, S. P., 17, 114, 591
Redbud, see Cercis canadensis
Reddy, C. S., (19)
Reed, H. E., 17, 287
Reilly, J. J., 473
Respiratory metabolism of Streptomyces scabies, 5
Rex, Edgar G., (236)
Rich, Avery E., 26
Rich, Saul, 17, (113), 114, 353, 457, 473, (477)
Richards, Sterling J., (35)
Richardson, J. K., 171, 297
Rhizoctonia microsclerotia, on soybean, 1
ramicola, on ornamentals, 287
solani, an incitant of alfalfa crown bud rot, 510
an incitant of root and rhizome rot of peppermint, 514
inhibited by Streptomyces sp., 473
on bean, 607
on forage legumes and grasses, 281
on jack pine seedlings, damping-off, 202
on lima bean, tolerance to, 515
on potato, control with chlorinated phenols, 512
on strawberry, 283
in Arkansas, 8
variation in culture, 473
sp., causing damping-off of conifer seedlings, 464
on grains, 468
on stock, 476
possible role in nematode celery disease, 13
spp., aerial blight of forage crops, 282
dried grain inoculum, 469
on soybean, 1
Rhizopus nigricans, post-harvest treatment for peach fruit, 341
Rhodotorula gracilis, inhibition point at various pH by helixin, 169
Rhopalosiphum maidis (aphid), barley yellow dwarf virus vector, 15
maize leaf-fleck virus vector, 683
prunifoliae, barley yellow dwarf virus vector, 15
maize leaf-fleck virus vector, 683
Rhubarb, bud rot (winter injury), reminiscence on, 512
Rhynchosporium secalis, in barley, field inoculation technique, 17
Ribes spp., eradication on burned-over area, 476
Rice (Oryza sativa),
white tip, control of incitant nematode, 6
laboratory culture of incitant nematode, 21
nematocide tests, 463
Rieman, G. H., (25), 26, (109)
Riker, A. J., (2), (13), (463), (467), (613)
Roach, Harry Q., (112)
Roane, Curtis W., 480
Roberts, D. A., 287, 381
Rochow, W. F., (473)
Rogers, C. H., 485
Rogers, J. B., (693)
Roistacher, Chester N., 171
Root graft, transmission of carnation mosaic virus, 21
Root injury, as a factor in assessment of chemotherapeutants, 311
reduction in disease severity of Fusarium wilt, 113
Root-knot nematode, see Nematodes: root-knot
Rosberg, David W., (79)
Rose, mosaic virus, 413
Rosen, H. R., 17
Ross, A. Frank, (464), 473, (540)
Roth, Elmer R., 287
Roth, Lewis F., 518
Rowell, J. B., (6), 17, (480)
Rushdi, M. K., 473
Rust, asparagus, 13
barley stem, on albino seedlings, 177
bean, pantothenic acid content of infected leaves, 481
Race 85 (new) in Maryland, 342
cedar-apple, inheritance of resistance in apple, 19
cereal, lysis of uredospore germ tubes by lime-sulfur, 70

Rust—*continued*
flax, disease development, 204
mint, physiologic races, 2
rye stem, overwintering of uredospores, 403
safflower, varietal differences in susceptibility, 5
short season adaptation, 474
Virginia pine, 10, 115
wheat, stem, fungicide test, 465
inhibition and counter-inhibition, 11
Rubber, black thread, 547
Ruga verrucosans var. **solanacearum** n. var., strain on tomato in Brazil, 402
Rutabaga (Brassica napobrassica), mosaic on, 2
turnip virus 1 on, 258
Rye (Secale cereale),
root rot, in Tennessee, 287
stem rust, overwintering of uredospores, 403

Saccharomyces cervisiae, effect of chloranil on fermentive enzyme systems, 11
inhibition point at various pH by helixin, 169
pastorianus, inhibited in the soil, 493
Safflower (Carthamus tinctorius)
foot and root disease, 211
Phytophthora root rot, testing for resistance, 219
varietal susceptibility, 5, 21
root rot, 32
rust, seed treatment, 108
varietal susceptibility, 5
Sambucus canadensis, tobacco ringspot virus on, 478
Samolus parviforis, curly top virus on, 2
Samson, R. W., (482)
Sasser, J. N., 17, 343, 474
Satureja vulgaris, mint rust on, 2
Savile, D. B. O., 474
Schechtman, A. M., (478)
Scheffer, R. P., 18, 474
Schlegal, David E., 519
Schmidt, C. G., (340)
Schmitthenner, A. F., 18, 474
Schneider, C. L., 18, 18
Schneider, Henry, 18, 18
Schreiber, Ray, (236)
Schroeder, Harry W., (468)
Schultz, E. S., (277), 343
Schuster, M. L., 211
Schwinghamer, E. A., 19
Scirrhia acicola, on loblolly pine, 282
Sclerospora **dichanthicola** sp. nov., on perennial forage grass in India, 598
graminicola, on corn, 675
macrospora, on corn, 675
Sclerotinia homeocarpa, dried grain inoculum, 469
on turf, fungicide tests, 22
sclerotiorum, on bean, fungicide tests, 477
on lettuce, 518
spp., growth rates, 471
Sclerotium rolfsii, on alfalfa, 1
on bean, 607
on Ladino clover, 1
on peanuts, 282
sp., on watermelon in Florida, 286
Scott, D. H., (468)
Sebek, Oldrich K., 119
Secale cereale, see Rye
Sedimentation, of virus particles, different in cucumber leaf and corolla preparations, 19, 420
Seed drying, corn, at high temperatures increases susceptibility to soil pathogens, 221
Seed germination, inhibited by extract from wood of Prunus spp., 285
Seed infestation, carrot with Stemphylium radicinum conidia, 217
Seed injury, corn, effect on emergence, 221
Seed maturity, corn, effect of drying on emergence, 221
Seed production, reduced in little leaf pine, 57
Seed transmission of disease,
cabbage black rot, 5
cherry, ringspot and yellows viruses, 4
soybean, fungi isolated from, 285
tall fescue net blotch, 22
tobacco mosaic virus in tomato, 114
Seed treatment, see also under Fungicides, specific compounds
comparison of dry and slurry application, 52
culture plate technique for agar diffusion assays, 447
alfalfa, for control of damping-off, 22
bean, for anthracnose, 1
for charcoal rot, 607
corn, varietal differences, 284
cucumber angular leaf spot, 107
legumes, 467
peas, 10
rice, white tip, various nematocides for control of, 6, 463
sugar beet, 13
wheat, smut, 10
tundu disease, 293
Segall, Ralph, (15)
Semeniuk, G., (20)
Senseney, C. A., 343
Septoria avenae, on oat, in Minnesota, 466
nodorum, longevity in stored grains, 13
Serological test for tobacco mosaic virus strains, 471
Setaria italica, Ephelis oryzae on, 634
Sexual reproduction of Hypomyces solani, 480
Sexuality of fungi, Chalara quercina, 438, 463
Shafer, William B., 519
Shands, H. L., (367)
Sharp, E. L., 263, 474, 480, 581
Sharvelle, Eric G., 19
Shaw, Charles Gardner, (479)
Shay, J. R., (11), 19
Shepard, C. E., (282), 287
Sherf, Arden F., 19
Sherwin, Helen S., (342), (469), 568
Shurtleff, M. C., 19
Shutak, V. G., (19)
Siegel, Albert, (464), 474, 519
Siegel, Benjamin M., (473)
Silky thread blight of ornamentals, seasonal relations, 287
Sill, W. H., Jr., 19, 328, 349, 420, 442, 474
Silverborg, Savel B., (547)
Siminoff, Paul, (91), (493)
Simmons, Marr D., 474
Sisler, H. D., 475
Skiles, Robert L., 20
Skoog, H. A., 475
Slack, D. A., (470), 475
Slagle, C. W., 240
Sloan, M. J., (15), (15)
Smart, Helen F., (481)
Smeby, R. R., 506
Smith, Albert L., 287
Smith, F. G., (263), (474), (480), (581)
Smith, Harlan E., 20, 20
Smith, M. A., (341)
Smith, N. R., (88), (249)
Smith, W. L., Jr., (341), 344, 475, 481
Smog, effect on oat leaf anatomy, 558
Smut, barley, covered —, factors affecting experimental inoculation, 117
loose —, inheritance of resistance, 367
mass inoculation of grain seed, 472
oat, seed treatments, 10
sorghum, seed treatments, 10
wheat, seed treatments, 10
Smut fungi, species concept and nomenclature, 479
Snapdragon, root-knot nematodes on, 637, 641
Snow mold, on forage crops, 5
Snyder, William C., (215), (479), 480

Soil fumigants, chloropicrin, for black shank of tobacco, 285
DD (dichloropropene-dichloropropane mixture),
on peanut, 282
on rye cover crop, 6
sweet potato cracking, partial control, 15
for control of golden nematode, 195, 345, 481
DD + chloropicrin, on peanut, 282
dichlorobutenes, for control of golden nematode, 195
Dowfume N, for control of golden nematode, 195
on peanut, 282
ethylene dibromide (Dowfume W-40)
for peanut root-knot, 282, 470
for potato golden nematode, 195
for rye cover crop, 6
for tobacco black shank, 15
methyl bromide, for black shank of tobacco, 285
for celery nematode, 13
Soil moisture, effect on safflower root rot development, 220
Soil organisms, isolated on sterilized straw in soil, 20
Soil sterilization, effect on soybean-nodule bacteria, 19
Soil temperature, effect on sweet potato internal cork lesions, 625
Soil treatment, Arasan for control of Fusarium disease of asparagus, 9
mercuric chloride, for control of snow mold, 5
sulfur, for control of sweet potato soil rot, 583
Soja max, see Soybean
Solanine, inhibitory to Colletotrichum phomoides, 1
Solanum sarchoides, weed host of Verticillium albo-atrum, 519
Solanum tuberosum, see Potato
Sorghum, smut, seed treatments, 10
Victoria blight, comparison of seed treatments, 10
Soybean (Soja max)
bacterial blight, halo strain, 299
as infection path for wildfire pathogen, 4
bacterial pustule, as infection path for wildfire pathogen, 4
foliage diseases, dried grain inocula, 469
frog-eye leaf spot, 660
fungi isolated from seed, 285
inoculation method for studies on charcoal rot and Diaporthe stem canker, 5
interaction of seed treatment and nodule bacteria inoculation, 19
Phyllosticta canker and leaf spot, in Maryland, 342
Rhizoctonia aerial blight on, 1
seed discoloration caused by Cercospora sojina, 568
wildfire, comparison of pathogenicity of six isolates, 4
Spinach, bacterial soft rot of packaged —, 475
cucumber virus 1, 4, 16
effect of host nutrition on virus concentration, 377
white rust, environmental factors, 448
predisposing factors, 17
studies on the pathogen, 473
Spongospora subteranea, as infection court in potato for Phytophthora infestans, 343
Spore dispersal of Phytophthora infestans, 323
Spore germination, effect of actidione, 21
fungitoxicity of various chemotherapeutants, 128
histological examination on cleared leaves, 352
Sporulation, comparison of two inoculation methods, 7
effect of light on several species of Dematiaceae, 342
Alternaria solani, effect of medium, 11
Phytophthora spp., substances stimulating to sexual stage, 24
Pyrenochaeta terrestris, pycnidial production of induced mutants, 183
Stemphylium solani, induced by ultra violet, 7
Sprague, Roderick, 475
Spreaders, see Fungicides, general: Spreaders
Spruyt, F. J., (193)
Squash, virus on, 8
winter, ringspot virus from tomato, 23
Staffeldt, E. E., 20
Stagonospora arenaria, compared with S. maculata, 653
maculata, on grass, 466, 653
meliloti, pathogenic on alfalfa, 513
Stahmann, M. A., (19), (25), (183), (420)
Stakman, E. C., (6), (480)
Staley, J. M., (476), (531), 691
Starr, Mortimer P., 114, (320)
Statistics, of half-tree plot technique of fungicide testing, 353
Steiner, G., 484
Steere, Russell L., 519
Stemphylium radicinum, on carrots, 215
as factor in carrot root scab complex, 9
sarcinaeforme, mechanism of tolerance to phenols and quinones, 473
solani, sporulation induced in culture, 7
on tomato, fungicide tests, 114
sp., on gladiolus causing red leaf spot, 363
Stessel, G. J., (6), 20
Stevenson, F. J., 277, 483
Stewart, Dewey, 344
Stewart, Donald M., 475
Stewart, R. N., (342)
Stock (Matthiola incana)
Fusarium wilt, physiologic races, 255
Race 3, 1
Rhizoctonia root injury, chemotherapy, 476
Stoddard, E. M., (72), 476, (651)
Stokes, G. W., (25), (26), (109)
Stomata, role in penetration in black rot of crucifers, 162
Stone fruits, virus invasion of immune varieties, 512
Stoner, Warren N., 683
Storage loss, control of fruit rots, 19
Storage, potato tubers, heat injury, 344
Storage rots, of small fruits, controls, 24
Storage temperature, effect on sweet potato internal cork lesions, 625
Stover, R. H., 476
Strawberry (Frageria chiloensis),
black root rot, 517
crown and root rot, 283
red stele, physiologic races of the incitant, 468
Rhizoctonia blight, 8, 283
root anatomy, 517
sting nematode on, 173
storage rots, controls, 24
Verticillium wilt, from weed host reservoir, 520
virus complexes, 20, 516
yellows virus complex, effect of temperature, 517
Streptomyces albus, Thiolutin from, 57
aureofaciens, inhibition of Bacillus subtilis in soil, 294
griseus, effect of cobalt on production of streptomycin and vtamin B-12, 123
ipomea, on sweet potato, 583
rimosus, inhibition of Bacillus polymyxa in soil, 294
scabies, inhibited on sweet potato by sulfur soil treatment, 589
respiratory metabolism, 5
stimulation of melanogenisis, 273
on potato, 26
venezuelae, production of chloromycetin in amended soil, 91
Strong, F. M., (506)
Strumella canker, eradication experiment, 287
Sufficool, J. R., (512)
Sugar beet (Beta vulgaris),
Cercospora leafspot, development of a resistant monogerm variety, 344
curly top virus, strains, 514
damping-off, control by antagonistic bacterium, 465
disease resistance breeding, 482
root rot fungus, host range, 18
seedling diseases, control, 13
vein clearing induced by leafhopper, 535
yellows, in U. S., 341

Sugarcane (Saccharum officinarum),
red rot resistance, 282
Pythium root rot, 12
inhibited by actinomycetes, 284
by bacteria, 464
by fungi, 469
mosaic virus, inheritance of resistance, 282
strains, 281
Sugars, in uredospores of various races of cereal rusts, 3
Sulfadiazine, inhibition of stem rust of wheat, 11
Sulfhydryl-containing compounds, inhibition of chloranil by —, 11
Survival ability of races of wheat stem rust pathogen, 479
SUTTON, DONALD D., (320)
SWAEBLY, MARY ANN, 476
Sweet potato (Ipomea batatas),
cracking, partial control, 15
internal cork, effect of temperature, 625
resistance and control, 287
root-symptomless clones, 428
soil rot, sulfur soil treatment, 583
storage-house fumigation, 513, 693
Sweet William (Dianthus barbatus), carnation mosaic virus in, root transmission, 21
SWENSON, K. G., 261
SYLVESTER, EDWARD S., 252
Syringa vulgaris, ring spot virus, graft transmission, 463
Systemic fungicides, see Chemotherapeutants
Systox, inhibitory to nematode hatching, 343

TAKAHASHI, WILLIAM N., 623, 690
Tangelo, Orlando (Citrus paridisi × C. reticulata), bud transmission of cachexia disease, 265
TAPKE, V. F., 117
TARJAN, A. C., 20, 114, 131, 637, 641
TAYLOR, A. L., (474), 484
TAYLOR, CARLTON F., 344
TAYLOR, GORDON S., 20, 476
TAYLOR, JACK, 288
Techniques, apparatus and equipment:
control chamber for growing plants, 59
culture plate for agar diffusion assays, 447
nephelometer, construction of a simple —, 171
settling tower inoculation technique for uredospores on cereal leaves, 340
soil fumigation, equipment, 193
sprayer, for concentrated fungicides, 3
Techniques, tests and methods:
accumulation of fungicides by spores determined by amylase inhibition, 471
agar plate method of testing inhibition of lesion-producing viruses by antibiotics, 331
bacterial inoculum, virulence maintained by deep-freeze method, 13
chemotherapeutants, test for activity, 127
chemotherapy, bioassay using bean wilt, 72
complement fixation for differentiating strains of TMV, 16
cytological preparations of fungi, 480
disease resistance, testing for multiple —, in tobacco, 5
dried inoculum, of foliar pathogens grown on grain medium, 469
field inoculation for testing barley resistance to scald, 17
fungicide tests using half-tree plots, 114, 353
fungitoxicity tests using spore germination in microbeakers, 519
germination tests, for seed corn in cold soil, simplified method, 11
host range, preliminary screening technique for seedling resistance to sugar beet root rot fungus, 18
inducing mutation of virus in vivo by nitrogen mustard, 25
inoculation, by tooth pick tip, for weak pathogens, 5
methods used for evaluating disease resistance, 628
of barley, for post-emergence smutting, 117
of flax with Fusarium, 515
of grain seed with smut spores, 472
Techniques—*continued*
of pear seedlings with Erwinia amylovora, 341
partial vacuum, quantitative pathogenicity tests for Ustilago zeae, 17
isolation, of single-spore or hyphal-tip, using reflected light, 118
of soil-borne phycomycete species, 341
jelly glass method for testing pathogenicity of Pythium spp. against red clover, 245
laboratory ED 50 related to field performance of fungicides, 113
leaf clearing with pyridine for examination of spore germination, 352
lyophilization of Puccinia uredospores, 263, 480
manipulation of crystalline inclusion bodies from mosaic infected tobacco, 519
nematodes, laboratory culture, 21
phloroglucinol tests for phony disease, 285
photometric method for determining growth of fungi, 11
plant growth inhibitors used for bean powdery mildew fungicide screening tests, 114
plating method unreliable as bioassay of black rot infestation of cabbage seed, 5
radioactive carbon labeled fungus material, 23, 431
radioisotopes used in study of microbial toxins, 483
rag-doll test for determining oat resistance to Victoria blight, 12
root-knot nematode identification by host reaction, 17
serological test using sheep red blood cells for TMV, 471
tissue culture, virus concentration in, 515
translocation study of viruses, 381
virus inactivation, test for effectiveness of water soluble compounds, 417
virus inoculation of leafhopper, 269
zoospore production for inoculum, Aphanomyces cochlioides, 18
Telia, of flax rust pathogen, factors influencing development, 207
Temperature, effect on disease development:
cabbage mosaic virus, resistance to and concentration of, 83
carnation bacterial wilt, 342
corn, damping-off, 221
crucifer black rot, symptom expression, 162
flax rust, 204
narcissus, Fusarium basal rot, 407
pepper, Verticillium wilt, 515
potato, tuber storage heat injury, 344
red clover, Pythium spp. on, 245
safflower root rot, 33, 219
spinach, cucumber virus 1 symptoms, 16
white rust, factor in pathogenesis, 17
strawberry yellows virus complex in vector, 517
sweet potato internal cork lesions, 625
tomato, Alternaria fruit rot, 425
Temperature, effect on specific pathogens:
Chalara quercina, growth and sporulation, 2
longevity, 470
cucumber virus 1, concentration in spinach, 4, 306
golden nematode, larvae viability, 113
Phytophthora infestans, viability of sporangia, 482
phaseoli, longevity of sporangia, 468
Pseudomonas phaseolicola, toxin production, 475
Puccinia graminis avenae, uredial development, 527
Rhizoctonia solani, growth, 473
Sclerotinia spp., growth rates, 471
Sclerotium rolfsii, growth, 1
THANOS, ANDREW, 21
THIRUMALACHAR, M. J., 596
THOMAS, C. A., 21, 108, 219
THOMAS, HAROLD E., (519)
THOMAS, H. REX, 43
THOMAS, W. D., JR., 21, 214
THORN, W. A., (478)
THORNBERRY, H. H., (2), (123), (289)

THORNE, GERALD, (77)
THORNTON, N. C., (476)
THURSTON, H. D., 481
Tilletia elymi, homothallic nature of, 635
TIMS, E. C., (22)
Tissue culture, concentration of virus in, 515
  growth of Uromyces caladii in, 479
Tobacco (Nicotiana tabacum),
  anthracnose, source of resistance among Nicotiana spp., 343
  black shank, breeding for resistance, 288
    effect of soil fumigation, 285
    estimating inoculum potential of soil, 286
    host-parasite relations in resistant and susceptible tobacco varieties, 286
    nematodes as a contributing factor, 15
    wilt mechanism, 472
  Brazilian streak virus, 231
  disease resistant fluecured varieties, factors in behavior, 284
  fungus infection related to guttation, 520
  Granville wilt, evaluation of resistance, 284
    inoculation methods, 629
  leaf curl virus, transmission studies, 343
  lethal virus, in fluecured area, 284
  mosaic virus, effect of plant regulators on infection, 517, 579
    inactivation study, 417
    resistance in Wisconsin tobacco, 8
    transmitted by grasshopper, 355
  multiple disease resistance, breeding program, 482
  ringspot virus, electron microscopy, 343
    transmitted by grasshopper, 357
  stem rot of partially cured tobacco, 10
  testing methods for evaluation of combinations of disease resistance, 5
  viruses, translocation of, 381
  wildfire, comparison of pathogenicity of six isolates, 4
    resistance, 12
TODD, E. H., 21, (463)
Tomato (Lycopersicon esculentum),
  alfalfa witches' broom virus in, 27
  Alternaria rot, temperature effect, 425
  anthracnose, control, 114
    effect of fungicides on pathogen, 470
    growth of pathogen inhibited by solanine, 1
    pathogen variation, 18
    resistance, 113
  curly top, new strain in Brazil, 396
  early blight, chemotherapy for, 7
    control with helixin, 168
    fungicide tests, 23
    races of the pathogen, 467
  fruit rot, pathogen variation, 18
  Fusarium wilt, chemotherapy for, 7, 465
    control with thiolutin, 338
    distribution of resistance throughout host, 474
    effect of foliar sprays, 3
    effect of plant regulators on susceptibility, 465
    possible use of ionizing radiation in therapy, 599
    root injury and chemotherapy, 113, 311
    wilting mechanism, 18
  gray leaf spot, control, 114
  internal browning, 591
    seed transmission of tobacco mosaic virus, 114
  late blight, meteorological correlation, 481
    races of the pathogen, 645
    resistance, 197
    source of resistance, 466
    susceptibility to physiologic races of the pathogen, 461
  root galls, induced by golden nematode, 466
  southern bacterial wilt, artificial inoculation, 23
    inoculation methods used for evaluating disease resistance, 628
Tomato—*continued*
    tobacco mosaic on, effect of date of inoculation, 463
      resistance to infection, 467
THOMPKINS, JOHN P., (8)
TOOLE, E. RICHARD, (438), 694
Toxicity, fluorine injury to vegetation, 112
  of amorphous droplets compared to crystalline forms of DDT and BHC, 200
Toxin, formation by microorganisms, 483
  from Verticillium, production and characterization, 472
  lycomarasmin, possible role in chemotherapeutic treatment of Fusarium wilt, 465
  produced by Pseudomonas phaseolicola, 475
  production, method for study with C^{14} labeled fungus material, 23
  relation to tissue respiration, 483
  wilt producing in raspberry, from Verticillium sp., 8
Transit diseases, potato, 112
Transit loss, control of fruit rots, 19
Translocation of viruses, independent of sugar translocation, 381
Trichoderma viride, production of gliotoxin by, 465
Trichothecium roseum, production of substance inhibitory to virus, 45
Trifolium, see Clover
TRUE, R. P., 21, (470), 476, (531), (537), (691)
TRYON, E. H., (21)
Tryptophan, effect on growth of tobacco mosaic virus in tissue culture, 467
Tuber formation, potato, associated with mycorrhiza, 25
  influence on scab infection, 297
TUITE, J., 476
Tulip, black rot of bulbs, 514
Tumors and tumor formation, see Galls
Tung, die back, 521
Turbidity, measurement of, with an easily constructed nephelometer, 171
Turf, see Grasses
Turnip, Phytophthora storage rot, 515
Turnip-greens, leaf spot control, 281
Tyloses, formation in oak wilt, 2
TYNER, L. E., 476
Typhula itoana, on turf, fungicide tests, 516
  spp., on winter wheat in Washington, 474

ULLSTRUP, ARNOLD J., 675
Ulmus americana, tobacco ringspot virus on, 478
  sp., spot anthracnose, 12
Urocystis cepulae, on onion, control, 469
  gladiolicola, sori in gladiolus corms, 578
Uromyces caladii, growth in tissue culture, 479
  caryophyllinus, carnation resistant to, 112
  phaseoli, infection of bean leaves related to guttation, 520
    pantothenic acid content of uredospores, 481
  phaseoli-typica, Race 85 (new) in Maryland, 342
Ustilago hordei, factors, 117
  nuda, barley seed treatment, 476
  spp., mass inoculation of cereal grains, 472
  zeae, colorless mutants, 480
    free amino acids and carbohydrates synthesized by, 6
    production of indole acetic acid by, 24
    quantitative pathogenicity test, 17
    sporidial mutants, 480

VAARTAJA, OLLI, 501
Vaccinium ashei, galls on, 249
  australe, galls on, 249
  irrgatum, silky thread blight on, 287
Vaccinium spp., see also Blueberry
VALLEAU, W. D., 21, 40, 288
VANDERMARK, J. S., (19)
VARNEY, E. H., 22, 477
Vasates cornutus (mite), responsible for yellow spot of peach, 443
VASUDEVA, R. S., 149, 291

VATTER, A. E., (3)
VAUGHAN, EDWARD K., 477, 519, (520)
VAUGHN, JOHN R., 22
VENKATAKRISHNIAH, N. S., 634, 668
Venturia inaequalis, gene pairs conditioning pathogenicity, 480
induced biochemical mutants, 479
Verticillium albo-atrum, inoculation technique, cotton, 288
on mint, control by heat treatment, 472
on pepper, factors affecting pathogenicity, 515
on potato, 25
production of exotoxin, 472
weed host of, 519
sp., four biotypes on raspberry, 8
Vesicle formation, in Puccinia coronata avenae, influence of pH and zinc, 474, 581
Vetch, anthracnose, 670
Vicia faba, see also Bean, broad
chocolate spot on, testing chemotherapeutants, 127
spp., see Vetch
Vigna sinensis, see Cowpea
Vinca rosea, alfalfa witches' broom virus in, heat inactivation, 27
Viruses, general:
antibiotics, inhibition of tobacco necrosis virus by toximycin, 20
chemical test for peach phony virus, distribution of wood giving positive reaction in inoculated trees, 468
Viruses, general:
chemotherapy of tobacco mosaic virus with 1182, 465
competition between two strains of tobacco mosaic virus, 464, 474, 519
complement fixation for differentiating strains of TMV, 16
concentration of Brazilian tobacco streak virus in necrotic and recovered leaves, 233
concentration of virus in cultured tissue, 515
concentration, related to air temperature in cabbage mosaic, 83
constitution of virus particles studied by deuteron bombardment, 472
cross-protection tests with five viruses from canning peas, 10
effect of plant regulators on tobacco mosaic virus, 517, 579
electron microscopy of virus particles from several orchid genera, 9
electron microscopy, preparation of material from cucumber corolla, 19, 420
environmental conditions affect concentration of cucumber virus 1 in spinach, 4
inactivation of bottlegourd mosaic by various plant extracts, 149
inactivation, test of 54 water soluble compounds on infectivity of tobacco mosaic virus, 417
infectivity correlated with chloroplasts in centrifugation of cucumber virus 1, 420
inhibition, by fungal growth products, 240
mechanism, by fungal growth products, 45
of cucumber virus 1 from oriental cucumber, 349
of virus infectivity by grasshopper buccal fluid, 357
inoculation, aluminum oxide as abrasive for tobacco mosaic virus, 2
phosphate effect, 137
silicon dioxide as abrasive for tobacco mosaic virus, 2
insect vectors, inability of virus to multiply in non-vectors, 113
invasion of immune varieties of stone fruits, 512
latent period and generation time of tobacco mosaic virus following inoculation, 520
multiplication of aster yellows virus in its insect vector, 14, 59
multiplication of virus following leaf inoculation, 520
mutations induced in potato virus X by nitrogen mustard, 25
mutation rates of several strains of tobacco necrosis virus, 156
Viruses, general—*continued*
nucleic acid study of red clover vein mosaic virus, 518
origination hypothesis for tobacco mosaic virus, 21
phloroglucinol test for phony disease, 285
phosphate effect, on infectivity of tobacco mosaic virus, 2
on plant virus inoculation, 137
primary lesions to determine relative susceptibility of plants, 113
protein polymerization in mosaic-diseased tobacco extract, 690
purification (partial), of tomato spotted wilt virus, 3
recovery of virus from non-vector leafhoppers, 470
recovery of water pimpernel from curly top, 2
resistance to reinfection by curly top virus strains in recovered plants of water pimpernel, 2
rod-like particles from "virus-free" potato plants, 466
seed transmission of virus from tomatoes showing internal browning, 591
serological test using sheep red blood cells, 471
specific transmission of viruses by leafhoppers, 663
translocation of sap-transmissible viruses, 381
transmission studies, 31
Virus(es):
alfalfa mosaic —, aphid transmission, 261
on bean, 344
red clover reservoir, 467
strains in potato, 516
alfalfa witches' broom —, control of spread, 649
host range and thermal inactivation, 27
apple dwarf fruit and decline —, 4
aster yellows —, evidence of multiplication of virus in its insect vector, 59
inability to multiply in corn stunt virus vector, 113
multiplication in its insect vector, 14
study on specific transmission by leafhoppers, 663
barley mosaic —, in Calif., 12
barley yellow dwarf —, symptoms and aphid vectors, 15
bayberry yellows —, 17
bean southern mosaic —, deuteron bombardment, effect on infectivity and serology, 472
inhibition by fungal growth products, 240
inhibition tests, 46
bean yellow mosaic —, cross-protection tests, 10
in Montana, 101
necrotic lesion strain, 24
on Gladiolus, 65
red clover reservoir, 467
beet mosaic —, aphid transmission study, 252
beet yellows —, in Washington, 516
bottlegourd mosaic —, host range, 149
cantaloupe mosaic —, in Calif., 8
carnation mosaic —, inactivated by zinc ion, 418
properties, 289
root transmission, 21
cereal yellow dwarf —, host range, 518
cherry little —, grafting experiments, 477
cherry mora —, 347
cherry necrotic ringspot —, strains and symptoms, 470
cherry ringspot —, effect on tree growth, 470
seed transmission, 4
separation, 517
cherry western X little —, effect on seed, 515
cherry yellows —, seed transmission, 4
separation, 517
chrysanthemum stunt —, symptoms increased under high intensity light, 341
Citrus tristeza —, grafting experiments, 280
clover (alsike) mosaic —, red clover reservoir, 467
clover (red) vein mosaic —, crystalline inclusions, 518
red clover reservoir, 467
clover (sweet) wound tumor —, multiplication in its vector, 269
corn (maize) leaf-fleck —, 683
corn stunt —, specificity of vector, 113
study on specific transmission by leafhoppers, 663

Virus(es)—*continued*

cucumber mosaic —, cowpea as an assay host, 328
cowpea strain susceptible to systemic infection, 442
electron microscopy, 19, 420
from pepper and alfalfa, 7
in Calif., 8
in Gladiolus, 65
in spinach, 16
effect of various factors on concentration, 4, 306, 377
temperature effect on disease development, 301
inhibitor from resistant cucumber, 349
strain 28, cross-protection tests, 10
translocation in plants, 381
transmission studies on poke, 6
cucumis —2C, host range, 149
curly top —, recovery of water pimpernel from, 2
elm —, strain of tomato ringspot, 477
elm mosaic —, transmitted to tobacco, 22
filaree red leaf —, studies, 110
grape, Pierce's disease —, vectors, 533
lettuce mosaic —, control, 573
local lesion hosts for, 478
lilac ringspot —, transmission, 463
muskmelon mosaic — (curcurbit ring mosaic —), in Calif., 8
muskmelon vein necrosis —, symptoms and host range, 8
Nicotiana glutinosa root necrosis —, 464
oat blue dwarf — (?), 471
oat mosaic —, in Calif., 12
oat red leaf — (?), 471
orchid diamond mottle —, 12
orchid flower breaking —, 12
orchid leaf and petiole mottle complex, electron microscope studies, 79
orchid leaf mosaic —, 12, 339, 178
orchid leaf patterning —, electron microscope studies, 9
orchid ringspot —, 12
orchid (Cattleya) —, serological detection of, 478
papaya bunchy top —, studies on, 3
pea common mosaic —, red clover reservoir, 467
pea enation —, cross-protection tests, 10
pea streak —, cross-protection tests, 10
red clover reservoir, 467
peach —, hot water treatment, 517
peach phony —, acid test studies, 468
phloroglucinol test, 285
reservoir in wild plum, 282
review of control program, 286
wild plum reservoir, 287
peach ringspot —, resistance conferred by mild strain, 512
peach X disease —, symptom variation, 519
symptoms on sweet cherry, 519
dodder transmission, 475
pepper ringspot —, strain of cucumber mosaic —, 7
Plantago mosaic —, possible origin of TMV, 21, 40
potato green dwarf induced by beet curly top —, 516
potato leaf roll —, aphids as vectors, 540
evaluation of phloroglucinol test, 481
immunological and histological relationship between strains, 26
influence on ascorbic acid content of tubers, 516
potato X —, in tobacco, transmitted by grasshopper, 357
mutations induced by nitrogen mustard gas, 25
relative concentration, 473
translocation in plants, 381
potato Y —, relative concentration, 473
radish mosaic —, particle size, 623
rose mosaic —, properties and host range, 413
rutabaga mosaic —, similar to turnip virus 1 group, 2
squash mosaic —, in Calif., 8
strawberry — complexes, 516
strawberry — 1 and 2, aphid transmission, 20
dodder transmission, 20
strawberry yellows — complex, effect of temperature, 517

Virus(es)—*continued*

sugar beet curly top —, new strain on tomatoes in Brazil, 396
strains, 514
sugar beet yellows —, in U. S., 341
sugarcane mosaic —, inheritance of resistance to, 282
strains, 281
sweet potato internal cork —, effect of temperature on symptom development, 625
resistance and control, 287
root-symptomless clones, 428
tobacco leaf curl —, transmission studies, 343
tobacco lethal —, new strain or complex, 284
tobacco mosaic —,
chemotherapy, 465
competition between two strains, 464, 474, 519
complement fixation for differentiating strains, 16
concentration in cultured tissue, 515
crystalline inclusion bodies, 519
deuteron bombardment, effect in infectivity and serology, 472
effect of carborundum on infectivity, 2
effect of P^{32} on concentration and symptoms in tobacco plants, 519
effect of plant regulators on infection, 517, 579
growth in tissue culture, 467
in tomato, effect of date of inoculation, 463
inactivated by thiamine hydrochloride, zinc chloride, 417
inhibition by terramycin, 333
inhibition tests, 46
latent period and generation time following inoculation, 520
possible intermediate protein in formation of —, 690
possible origin, 21, 40
relation to internal browning of tomato, 591
resistance in tomato, 467
resistance in Wisconsin tobacco, 8
rib grass strain, compared with virus from tomatoes showing internal browning, 592
serological test, 471
strain 1952D, primary necrotic lesions, 113
strains, seed transmission in tomato, 114
translocation in plants, 381
transmitted by grasshopper, 355
tobacco necrosis —, inhibition by toximycin, 20
inhibition of lesions by antibiotics, 331
inhibition tests, 46
mutation rates of 11 strains, 156
tobacco ring spot —, electron microscopy, 343
in Gladiolus, 65
inhibition of lesions by antibiotics, 331
translocation in plants, 381
transmitted by grasshopper, 357
woody hosts, 478
tobacco streak —, Brazilian, 231
tomato ringspot —, from elm, 477
in winter squash, 23
tomato spotted wilt —, partial purification and electron microscopy, 3
turnip mosaic —, effect of host nutrition on concentration of —
in Nicotiana spp., 477
from rutabaga, host range and properties, 258
in Ontario, 2
western watermelon mosaic —, aphid vector, 8
wheat mosaic —, in Calif., 12
wheat yellow streak mosaic —, effect of temperature on pathogenesis, 474
wild cucumber mosaic —, in Calif., 8

Vitamins, see also Micronutrients, vitamins
B_1, inactivation of tobacco mosaic virus by, 417
inhibitory to inoculation of Colletotrichum lagenarium on cucumber, 478
B_{12}, effect of cobalt on production, 123

Vitamins—*continued*
folic acid, role in stem rust of wheat, 11
pantothenic acid, content of rust infected bean leaves, 481
para-amino benzoic acid, role in stem rust of wheat, 11
Vitis californica, sooty blotch, 518
Vitis spp., see also Grape
Volutella sp.:, on alfalfa and clover, 5

WADLEY, BRYCE N., 519
WAGGONER, PAUL E., 22, 323, (465), 477, 599, 645
WALKER, J. C., (19), (25), (65), (105), (162), (183), (316), (328), (349), (420), (442), (469), (474)
WALLACE, A. T., (283)
WALLACE, H. A. H., (13)
WALLIN, J. R., 482, (645)
Walnut, Hendersonula toruloidea on, carbohydrate-nitrogen ratio in disease development, 478
WALTER, JAMES M., 197, 236
WALTERS, H. J., 355
WARID, W. A., 22
Watermelon, Sclerotium sp. on, 286
western — virus on, 8
WATERTOR, JEAN L., (467)
WEATHERS, LEWIS G., (377), 477
WEAVER, ERNEST P., (16)
WEBB, T. E., (283)
WEBB, R. E., 26
WEBER, GEORGE F., (287)
WEBER, PAUL V. V., 22
WEDDING, R. T., (603)
Weed killers, effect on potato tubers, 25
WEED, RICHARD M., (14), (15), 477
WEINTRAUB, M., (2), (258), 417
WELCH, J. E., (573)
WELLS, HOMER D., 22
WELSH, MAURICE F., 477
WERNHAM, C. C., (467)
WESTER, R. E., (43)
Wheat (Triticum spp.),
earcockle nematode, 291
head blight, development, 453
leaf rust, mutant strain of the incitant, 479
longevity in storage of several cereal seed fungi, 13
mosaic virus, new, in Calif., 12
powdery mildew, reaction of resistant and susceptible varieties, 8
root rot, in Tennessee, 287
smut, seed treatments, 10
snow mold, control, 475
stem rust, fungicide test, 465
inhibition and counter-inhibition, 11
survival ability of races of the pathogen, 479
tundu bacterial disease, 291
Victoria blight, comparison of seed treatments, 10
yellow dwarf virus of barley on, 15
yellow streak mosaic virus, effect on temperature on pathogenesis, 474
WHEELER, H. E., 23, (284), 431, 483
WHITE, IRENE, 288
WIANT, JAMES S., (112)
WIEHE, P. O., 521
WILDMAN, SAM G., (474), (478)
Wilds, George James, Jr., biographical sketch, 485
WILES, A. B., 105, 288
WILHELM, STEPHEN, (517), 519
WILKINSON, R. E., 23, 478
WILLIAMS, H. E., (512)
WILLIAMS, LANSING, 478
WILLIAMS, ROBLEY C., (519)
WILLISON, R. S., (417)
WILSON, E. E., 478, 520
WILSON, J. D., 23
WILSON, NORTON S., 443
WILSON, R. A., (341)
Wilting mechanism, in tobacco black shank, 472
in tomato Fusarium wilt, 18
Wind dispersal of spores, 323
WINSTEAD, N. N., 23, 628
WINTER, H. F., 23
WOLCYRZ, SYLVIA, (240)
WOLF, FREDERICK A., (147)
WOLF, FREDERICK T., 24, 147, (288)
WOMELDORPH, S. E., JR., (341)
Wood decay, reduced by soil cover in basementless houses, 341
Wood preservatives, histological technique for study of, 300
WORTHINGTON, JOHN T., (425)
Wounds, relation to infection in black rot of crucifers, 162
WRIGHT, C. M., (513)
WRIGHT, W. R., (341)
WU, Y. S., 177

X protein, possible intermediate in formation of TMV, 690
Xanthomonas campestris, Brassica spp. resistant to, 497
in cabbage seed, 316
penetration and symptom types, 162
studies on seed transmission, 5
malvacearum, varietal resistance in cotton, 98
phaseoli, chemotherapeutants, 72
in apparently healthy pinto beans, 214
var. fuscans, in apparently healthy pinto beans, 214
pruni, control on peach by dormant spray, 14
translucens, on grasses and cereals, 387

YALE, JOHN W., 520
YARWOOD, C. E., 137, 478, 481, 520
YOUNG, ROY A., 26, (513), 520, (693)
YOUNG, WILLIAM J., (2), 24
YOUNKIN, S. G., 114

ZAITLIN, MILTON, 478
Zantedeschia elliottiana (yellow calla), bacterial chalk rot, 320
rhamanni (pink calla), bacterial chalk rot, 320
ZAUMEYER, W. J., (7), 24, 344
Zea, mays, see Corn
ZENTMEYER, GEORGE A., 24, 35, 478
Zinc, see also Micronutrients
chloride, inactivation of tobacco mosaic virus by, 418
sulfate, inactivation of tobacco mosaic virus by, 418
Zoospores, technique for production in Aphanomyces spp., 18
ZUCKERMAN, BERT M., (6)

ERRATA, VOLUME 41

Page 1078, line 4, read Except where stated otherwise the variety used was Warba.

ERRATA, VOLUME 42

Page 61, column 2:
line 8, *read* 40-day *for* 19-day
line 9, *read* three times weekly or every 5 days *for* three times weekly.
line 12, *read* to fresh asters after an initial period of 19 days on rye *for* to fresh asters

Page 119, footnote 1, line 2, *read* 242 *for* 000

Page 123, footnote 2, line 2, *read* student with reference to a course in Plant . . . .

Page 125, table heading, line 4, *read* μg./ml. *for* mgm./ml.

Page 180, column 1, line 59, *read* semiweekly *for* biweekly
column 2, line 7, *read* Height increase of inoculated plants *for* Height of inoculated plants

Page 197, column 2, line 15, *read* Manasota have resistance to W only *for* Manasota:

Page 211, column 2, line 5, *read* pycnial *for* pycniseal

Page 219, column 2, line 20, *delete* again

Page 259, line 40, *read* Millon's reagents *for* Millions reagents

Page 273, column 2, line 17, *insert* (2, 14) after tissues of higher plants

Page 277, line 4, *read Solanum for* colanum

Page 296, line 6, *read* biotics. We could not demonstrate the presence of terramycin *for* biotics in liquid culture media the antagonistic effects

Page 335, column 2, line 16, *insert* [3] between was. and It did

Page 346, Table 2, line 7, *read* tuberosum L. *for* tubersum L.

Page 353, lines 8-9 *read* Minimizing the influence *for* The minimizing influence

Page 408, Table 1, footnote d *read* Number of plants with symptoms/number *for* Number of plants with symptoms number tested

Page 430, line 20, *omit* period after cork

Page 437, column 2, line 22, *read* mount *for* amount

Page 438, Table 1, line 12, *read* Hamblen Co. for Hamilton Co.

Page 506, line 26, capitalize Streptomyces.

DIFCO

Culture Media for Fungi

This group of Dehydrated Culture Media, Difco, is prepared expressly for propagation of the fungi most frequently encountered in phytopathological studies. Each medium is readily prepared for use and requires no adjustment of its reaction or filtration of the solution.

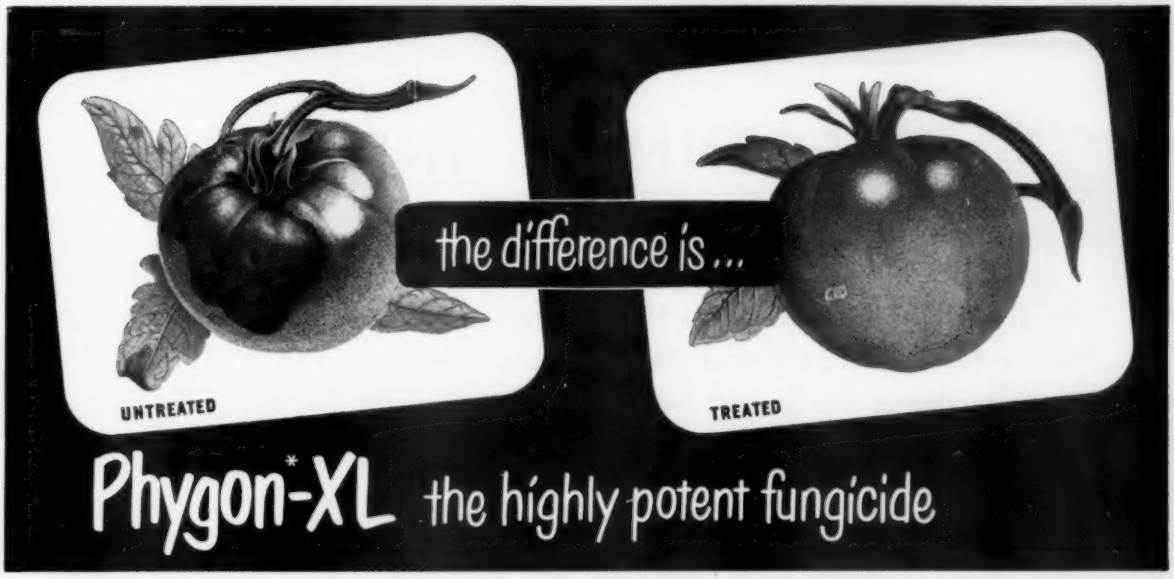
Bacto-Bean Pod Agar
Bacto-Corn Meal Agar
Bacto-Lima Bean Agar
Bacto-Malt Agar
Bacto-Potato Dextrose Agar
Bacto-Prune Agar
Bacto-Wort Agar
Bacto-Malt Extract Broth

The DIFCO MANUAL, containing discussions of our extensive line of Dehydrated Culture Media and ingredients of Culture Media, is available on request.

Specify "DIFCO"

DIFCO LABORATORIES

DETROIT 1, MICHIGAN



Phygon*-XL the highly potent fungicide

Controls with outstanding results, tomato late blight ...apple scab...bitter rot of apples and peaches...brown rot and brown rot blossom blight of peaches...cherry leaf spot...azalea petal blight...celery blight...black spot of roses...bean anthracnose and many other plant diseases. Phygon-XL has proved to be the most potent non-mercurial fungicide commercially available.

Results: Increased yields and higher quality of plants and fruit.

Advantages: Low cost, easy to use, highly compatible, harmless to pollen and bees, gives no unpleasant flavor and odor to crops.

*U.S. Pat. No. 2,349,772

UNITED STATES RUBBER COMPANY
Naugatuck Chemical Division, Naugatuck, Conn.

producers of seed protectants, fungicides, miticides, insecticides:
Spergon, Phygon, Aramite, Synklor.

GOOD BUY, Microscope Slides!
BEST BUY, TRIARCH Slides!

1. Prepared microscope slides have risen in price less than any other laboratory equipment, and TRIARCH SLIDES have risen less than most.
2. TRIARCH SLIDES are carefully selected to show the structures you want, and to avoid artifacts.
3. TRIARCH SLIDES are always shipped on approval with privilege of 10 day examination.
4. TRIARCH makes no extra charge for containers or shipping costs.
5. TRIARCH QUADRUPLE STAIN is excellent for pathological tissues.
6. TRIARCH offers largest available collection of slides of phytopathological items.

Watch for special announcements in our occasional publication, TRIARCH TOPICS, and write for a copy of our current catalog.

GEO. H. CONANT
TRIARCH BOTANICAL PRODUCTS
RIPON, WISCONSIN

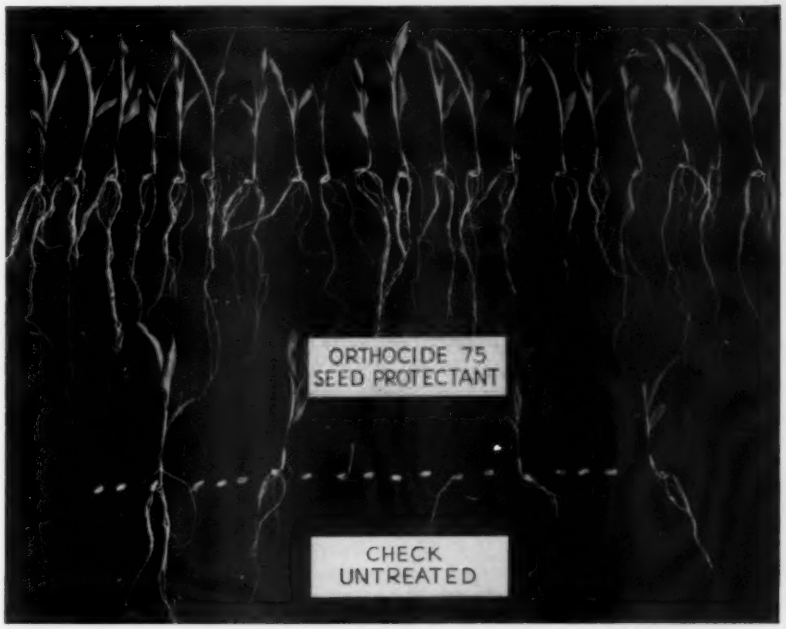
DECENNIAL INDEX

A DECENNIAL INDEX for Volumes 31 through 40 is available now. The INDEX covers years 1941-1950. Members may wish to bind the index with Volume 40. It is sold separately, that is, subscription to PHYTOPATHOLOGY or membership in the Society does not entitle one to the INDEX. The price is $3.50.

Remittances should be sent with orders to

Dr. A. E. Dimond
PHYTOPATHOLOGY
Connecticut Agricultural Experiment Station
P.O. Drawer 1106, New Haven 4, Conn.

ORTHOCIDE 75
Seed Protectant



Hybrid Seed Corn #620

Treatment		Average Percent Emergence (4 Replicates)			
		10/25/51	10/28/51	6/6/52	6/9/52
ORTHOCIDE 75 Seed Protectant	2/3 lb/gal/32 bu.	80%	92.5%	92.5%	95%
ORTHOCIDE 75 Seed Protectant	1 lb/gal/ 32 bu.	85%	95%	98.75%	98.75%
ORTHOCIDE 75 Seed Protectant	1 1/3 lb/gal/32 bu.	91.2%	96.2%	95%	97.50%
Standard Treatment	1 lb/gal/32 bu.	65%	85%	72.50%	86.25%
Check, no treatment	———	25%	33/7%	42.50%	46.25%

Seed was treated commercially by Edward J. Funk & Sons, Kentland, Indiana

• *Write for booklet containing full information on ORTHOCIDE 75 Seed Protectant, including results of over 50 tests on many different crops.*

ORTHO

TM's ORTHOCIDE, Reg. U.S. Pat. Off.

World Leader in Scientific Pest Control

CALIFORNIA SPRAY-CHEMICAL CORP.

Home Office: RICHMOND, CALIFORNIA

Portland, Ore.
Sacramento, Calif.
San Jose, Calif.
Fresno, Calif.
Whittier, Calif
Caldwell, Idaho
Maryland Heights, Mo.
Oklahoma City, Okla.
Shreveport, La.
Orlando, Fla.
Linden, N. J.
Fennville, Mich.
Medina, N. Y.
Goldsboro, N. C

Plus 25 Branch Offices throughout U.S.A.

EUROPE: California Spray-Chemical Compagnie, Francaise, S.A.R.L.
33 Avenue des Champs Elysees, Paris 8, France

Plant Pathologist, G. C. Kent is a member of a team of specialists sponsored jointly by the Mutual Security Agency and the Philippine Government to work with and help train members of the Philippine College of Agriculture staff. Dr. Kent will be concerned with teaching and with research on diseases of rice, corn, vegetables, and other crops. He will be located in the Philippines for approximately one year.

A questionnaire will be mailed in December to all members of the Society to obtain the detailed information desired for the new Membership List or Directory. It is important that information requested be supplied exactly as called for since the cards will be forwarded directly to the printer. Information requested will include: name, title, address, and field of interest. The deadline for receipt of the information is February 1. Any members delinquent in their dues beyond this date will not be included.

Phytopathologist, A. Frank Ross of Cornell University is spending part of a sabbatical leave at the Agricultural Experiment Station, University of Puerto Rico, Rio Piedras. While there he will engage in research on virus diseases of papaya, pineapple, potato, and pepper. He expects to return about May 1, 1953.

A symposium on Viruses and the Protection of the Plant Kingdom (Les Virus et la Protection du Régne Végétal) was held on Oct. 1, and 2, 1952, in conjunction with the Centenary of Laval University, 1852-1952, under the auspices of the Quebec Society for the Protection of Plants, at Quebec City. Speakers invited from the U. S. were Phytopathologists, R. H. Larson, University of Wisconsin and F. O. Holmes, Rockefeller Institute for Medical Research.

Phytopathologist, L. Carl Knorr will return to the Citrus Experiment Station, Lake Alfred, Florida after 2½ years of research on the tristeza disease of citrus in Argentina. The recent discovery of this virus disease in Florida has led to the decision to close the Tristeza Laboratory in Argentina after 6 years of cooperative investigations between the State Plant Board of Florida and the Argentine Ministry of Agriculture.

Several articles worth reading have been suggested by the Public Relations Committee. They were published in International Conference in World Affairs, Fernhurst, England 1951.

"Wastage of world food supplies through pests and diseases"—Sir John Russell.

"Fungicides: Their development and uses"—P. W. Brian, et al.

"Control of Plant virus diseases"—F. C. Bawden.

The Southern Division will meet in conjunction with the Association of Southern Agricultural Workers at New Orleans, Feb. 9-11, 1953. It is anticipated that approximately 40 papers will be presented by pathologists attending. The convention headquarters will be in the Jung Hotel.

The Northeastern Division held its Annual Winter Meeting at West Springfield, Mass., on Nov. 6 and 7, 1952 with over 75 persons in attendance. Fifteen technical papers were presented and the abstracts will be published in a subsequent issue of *Phytopathology*. The guest speaker on Nov. 6 was Dr. B. M. Duggar who chose as his topic, "Sixty Years of Plant Research—Reminiscences." At the morning session on Nov. 7, Dr. D. H. Palmiter presented a Kodachrome illustrated talk, "Impressions of the West and some of its Stone Fruit Virus Problems." Officers elected for 1953 are: S. G. Younkin, President; J. S. Tidd, Vice-President; A. B. Burrell, Secretary-Treasurer; F. O. Holmes, Councilor. The Division was invited to New Hampshire and Maine for its summer meeting in 1953—the location to be chosen by the Executive Committee. An invitation by the Eastern State Farmers' Exchange, Inc., for the Division to hold its 1953 winter meeting in West Springfield was unanimously accepted.

Deaths, Dr. Kogo Togashi, Yokohoma National University passed away July 21, 1952 at the age of 57 following a long illness.

Editor: K. W. KREITLOW, Plant Industry Station, Beltsville, Md.

THE RESULTS OF PLANNING

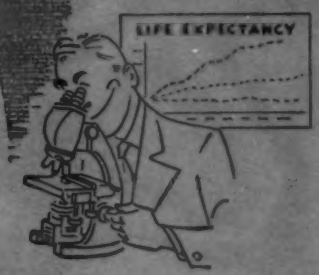
Fall and its harvests bring the answer to many well-laid plans of the research worker, extension worker, and the grower. Continuing crop goals, causing some shifts in farm practices, make new demands on the responsibilities of advisory forces —demands which will undoubtedly increase as conditions change. Careful checks on the year's results, especially in relation to fertilization practices, can but aid in efficient production without soil depletion—a necessity if American agriculture is to remain permanently on a high level.

AMERICAN POTASH INSTITUTE, INC.

1102 Sixteenth Street, N. W. **Washington 6, D. C.**

Member Companies: American Potash & Chemical Corporation
Potash Company of America • United States Potash Company

LONGEST LIFE EXPECTANCY



of any laboratory microscope ever made

BAUSCH & LOMB *Dynoptic* LABORATORY MICROSCOPES

Frictionless Dynoptic design reduces wear . . . gives you unequalled focusing ease . . . adds many years to the life of your Bausch & Lomb Laboratory Microscope. Entire fine focusing system floats on ball bearings and rollers . . . never binding, never drifting out of focus.

To this, and the many other long-life mechanical features, is added the world's finest optical system, resulting in *the world's finest laboratory microscope.*

Write for FREE DEMONSTRATION and LITERATURE. See for yourself how Bausch & Lomb Dynoptic Microscopes outperform any laboratory microscope ever made. Bausch & Lomb Optical Co., 66512 St. Paul St., Rochester 2, N. Y.

PROTECTION through RESEARCH

STAUFFER AGRICULTURAL RESEARCH LABORATORY
Fremont Road, Mountain View, California

This is where initial screening is done on all new Stauffer insecticides, fungicides, herbicides and soil fumigants.

Only those products showing exceptional promise in this preliminary screening are released to experiment stations for use in their pest control investigations.

These rigid lab tests and extensive field trials are standard procedure before any Stauffer product is merchandised.

SULPHUR
Paste, Wettable, Dusting, Flowers, Burning

DDT • LINDANE • BHC • CHLORDANE
TOXAPHENE • PARATHION
ALDRIN • DIELDRIN
Wettable, Emulsifiable, and Dust Concentrates
Dust Mixtures

TEPP • Sulphenone • DDD • Fungicide 406

POTASSIUM NITRATE
A convenient source of Potassium and Nitrogen in hydroponic mixtures

CALCIUM ARSENATE

BORAX

Stauffer CHEMICALS SINCE 1885

STAUFFER CHEMICAL COMPANY

420 LEXINGTON AVE., NEW YORK 17, N. Y.

636 CALIFORNIA STREET, SAN FRANCISCO 8, CALIF.